DIFFERENTIATION THEORY : INTERSENSORY SUBSTITUTION AND THE USE OF THE SONICGUIDE

Stuart Aitken

Doctor of Philosophy
University of Edinburgh
1981

I hereby declare that this thesis is my own work, having been completed within the normal terms of reference and of supervision in the Faculty of Social Sciences, University of Edinburgh

Stuart Aitken

ACKNOWLEDGEMENTS

I would first like to thank my supervisor, Dr. T.G.R. Bower. Throughout the duration of this thesis he has been a consistent source of support and encouragement, as well as showing a lively interest in the research. Secondly, I am grateful to Wormald Vigilant for supplying one of the Sonicguides used in these studies. The Science Research Council and Medical Research Council funded these studies. Additional funding was provided by the Ross Foundation for the Blind.

In carrying out the research with blind infants and children, many people provided generous assistance. Drs. Jane D. Turnbull and Jennifer G. Wishart supplied video-tapes of observations made during previous sessions. Marlene Stafford, Parent Counsellor for the Blind in East Scotland, cut through much of the red tape enabling me to visit several blind children. Mr. B. Aitken, Headmaster of the Royal Blind School, Edinburgh, permitted access to his school for several visits. Dr. Irene Neilson allowed me to accompany her on visits to two blind children, as well as providing video-tapes for re-analysis. In addition, I would like to thank the parents of these children, without their help much of the work would have been impossible.

In carrying out the work with sighted infants, Jacqueline Kujaswki and Sarah Stone contributed a great deal of time and effort to ensure that this research ran smoothly.

I would also like to thank the parents of the infants who participated in these studies, particularly those who took part in the long-term studies. Dr. Ludlum, Clinical Co-ordinator Community Health Service, allowed access to local schools. Mrs. Cameron, Infant Mistress at Moredun Primary School, permitted access to children on several occasions. The technical services of J. Gordon, J. Duncan, J. Cuthbert and D. Wight are also greatly appreciated.

I am also very grateful for the many helpful comments and criticisms of Dr. Jennifer G. Wishart, whose patience and accessibility has been a constant source of support. Rodney S. Noble (particularly with computer work) and Duncan H.C. Robb both provided many hours of valuable discussion. Last, but not least, I wish to thank my wife, Denise, for her support in the past three years.

ABSTRACT

This thesis investigates the possibilities and parameters of intersensory substitution - the provision through one sense of information normally provided through another sense. An artificial ultrasonic echo-location device, providing, through sound, information usually provided through sight, was used. A series of interlinked cross-sectional and longitudinal studies was run, using both blind and simulated blind subjects of a range of ages. Infants, pre-school children, school-age children and adults were tested. Although some subjects in all age groups were shown to be able to make some use of the device, by adopting strict criteria for testing the effectiveness of this use, both qualitative and quantitative age differences in use were demonstrated to exist. The implications of these results for conflicting theories of development, in particular perceptual development, are considered. A differentiation theory in which development is seen as proceeding from abstract to specific, while not consistent with all the results, is shown with modification, to have the greatest explanatory value.

TABLE OF CONTENTS

Page no.

CHAPTER 1: INTRODUCTION

Page no.

CHAPTER 2 - A CROSS-SECTIONAL SONICGUIDE STUDY OF THE BLIND

CHAPTER 3 - LONGITUDINAL STUDY OF BLIND SONICGUIDE USERS

Page no.

CHAPTER 4 - CROSS-SECTIONAL STUDY OF SIGHTED SUBJECTS' USE OF THE SONICGUIDE

Page no.

CHAPTER 4 Cont.

Page no.

CHAPTER 5 - LONGITUDINAL STUDY OF SIGHTED INFANTS' USE OF THE SONICGUIDE

Page No.

CHAPTER 6 - STIMULUS PARAMETERS OF THE SONICGUIDE

CHAPTER 7 - DISCUSSION OF THE THEORETICAL IMPLICATIONS OF THESE FINDINGS

CHAPTER 1 - INTRODUCTION

INTERSENSORY SUBSTITUTION: THE PROBLEM OF THE UNITY OF THE SENSES

The subject of this thesis is intersensory substitution. The study of intersensory substitution is the study of the extent to which one sense can provide the organism with information normally provided by another. There are three classic lines of approach to this kind of problem. One approach, which was first stated in the nineteenth century by Johannes Müller, would argue that each sense provides us with its own specific inputs; there is thus no possibility of any genuine substitution between senses, or indeed of equivalence between senses: we cannot hear colours or see tones. Proponents of this view, from the nineteenth century to the present day, have been forced to admit that at some levels two different senses can pick up the same information: we can see that a stone is hard and we can feel that a stone is hard. How could this perceptual equivalence arise within the doctrine of specific energies of nerves? The answer, according to many theorists (e.g. Birch and Lefford, 1963), is a process of learning in which the specific inputs from one sense are associated with inputs of another.

The empiricist view outlined above was opposed by Gestalt psychologists. For example, von Hornbostel (1925) after Heider (1912), suggested that there was a unity of the senses, and that transfer could occur from one sensory modality to another, transfer which he described as a transposition phenomenon. Von Hornbostel argued that brightness, for instance, is common to sounds and smells as well as to colours, and that transposition would occur along this dimension regardless of the sensory modality. Köhler (1929) described a similar instance with his classic "maluma/takete" distinction where transposition was found to occur between the words and their visual designs. The Gestalt psychologists of course were nativists, allowing learning a very minor role in the genesis of the perceptual world.

A third view, which is again at variance with the notion that "a nerve and when stimulated at all always gives rise to its own peculiar sensation" (Pillsbury, 1934), is that suggested by Heinz Werner (1948). He, like von Hornbostel, believed that there was a primitive organic unity of the senses. Werner cited synaesthesia as indicating unity of the senses, with tones producing a perception of colour being one example of a stimulus exciting a sensation in another modality. Synaesthesia is in this view regarded as reflecting the perception of supramodal qualities. If true, then results interpreted as evidence, for instance, of cross-modal transfer (Blank and Bridger, 1964) would neither be cross-modal nor would they involve transfer, but would rather involve the same supramodal mediating linkage. Werner sought to produce a theoretical basis for development which encompassed comparative work with animals as well as human development. His theory of differentiation was biological and suggested that at birth the neonate, because of neural undifferentiation in the brain, would perceive light as sound as smell as touch and so on. Later, there would be a process of differentiation, again biologically determined, in which the senses would become distinct. Later still, as long as the maturing organism was supplied with a rich sensory input, sensory re-integration would take place. The biologically deterministic nature of his theorising is reflected in the notion of ontogeny repeating phylogeny (Langer, 1970), where, for instance, the suggestion is made that cross-modal transfer occurs more readily in animals lower down the phylogenetic scale. Hence the coinage of the term "primitive" in the notion of unity of the senses. The difference between this and the second view is in the course of development of unity of the senses. The second view argues that no age differences should occur in intersensory substitutability. The Wernerian view would argue for a decrease in intersensory substitution with age.

There has not been a great deal of work on intersensory substitution as a natural phenomenon. An exception is the classic work on the "facial vision" of the blind, a term that reflects the influence of the doctrine of specific nerve energies. This was originally accounted for as being due to an uncanny sensitivity to the displacements of air currents striking the blind person's face. Terms such as "facial vision", "obstacle sense" and "sense of orientation" have all been used to describe this apparent phenomenon. All have in common that they suggest the presence of an additional 'sixth sense'. Dallenbach and his co-workers, however, in a well-controlled series of experiments have shown that there is no special 'skin sense' in blind people, but that obstacles were being detected by sound changes, for instance, by changes in the sound of their footsteps on approaching objects (Cotzin and Dallenbach, 1950; Supa, Cotzin and Dallenbach, 1944; Worchel and Dallenbach, 1947). It appeared then that the blind were detecting information about approach of obstacles in a manner akin to the sonar system of the bat (Simmons, Howell and Suga, 1975) with sound substituting for vision in the control of movement. A similar phenomenon has been shown by Dodds (1979) in demonstrating the extent to which vision can spontaneously substitute for audition in speech perception.

Apart from these studies, psychologists have by and large concentrated their efforts on the construction and elaboration of various artificial paradigms designed to investigate the nature of how objects can be experienced as having properties normally associated with other modalities through stimulation in only one modality. These paradigms have variously been termed inter-modal matching (Meltzoff and Borton, 1980), cross-modal matching (Bryant et al 1972; Ettlinger and Blakemore, 1967), cross-modal transfer, of which Blank and Bridger (1967) distinguish two kinds - cross-modal equivalence and cross-modal concepts, and inter-modal perception (Spelke, 1979). Although differing in methodology, each of these approaches was initiated in an effort to show to what extent there is some degree of co-ordination between the senses, or inter-sensory co-ordination. Since none would now deny that there is some degree of intersensory equivalence in adults, the main thrust of research has been the developmental dimension. Does intersensory co-ordination improve as the empiricists would claim, show no change as the nativists would claim, or show a decline as differentiation theorists would claim? The results from standard developmental studies are, to say the least, mixed.

DEVELOPMENTAL STUDIES OF INTERSENSORY CO-ORDINATION

The most influential developmental theorist who argued for initial sensory specificity with later sensory integration was Piaget. In his earlier work (e.g. Piaget, 1936, 1937) he reflected such a view, although more recently his line of argument has changed (Piaget, 1978). His view of initial sensory specificity was incorporated within his wide-ranging genetic-epistemological theory of development. In this theory, it is the child's action on the environment leading to secondary circular reactions which later promotes the infant's knowledge that seen objects will be tangible, objects which can be heard can be seen and so on. This view therefore argues for a greater degree of intersensory co-ordination in the adult or older child than in the young infant. Birch and Lefford (1963, 1967) have argued from their own experiments that transfer between sensory modalities improves as the child grows older. Zaporozhets (1965) has argued along similar lines. It should be noted that for Piaget behaviour is primary. In his theory, motor behaviours emerge and seize on the information given; if no information is given, the behaviour will die away. Stimulus information thus has an alimentary rather than a prescriptive role. More conventional empiricist views have been put forward by those working with younger infants in auditory/visual, visual/tactile and auditory/tactile tasks. Dodwell, Di Franco and Muir (1976), Field (1976, 1977), Lasky (1978) and Ruff and Halton (1978) have all obtained evidence in visual/tactile tasks which failed to support any contention that infants begin life with an undifferentiated perceptual system. Using an auditory/visual paradigm, McGurk, Turnure and Creighton (1977) and Mendelson and Haith (1976) have also found no evidence for initial co-ordination between the senses. All of this work has been based on the assumption that development is either a process of nature - a nativist view - or of nurture - the empiricist view. Although no current proponent of extreme nativism can be found and probably no current exponent of extreme empiricism can be found either (except, perhaps, for McGurk, Turnure and Creighton, 1977), nevertheless development is seen as occurring in an incremental fashion.

In contrast to these studies, Bower has presented data indicating that development is a complex process of differentiation. Development is seen as a process of differentiation, with later modality - specific information pick-up overlaying the antecedent modality free information pick-up. In support of this view, several lines of experimental evidence can be cited. Take, for example, studies of early auditory-visual co-ordination. Pratt, Nelson and Sun (1930) found that presentation of a sound in light resulted in visual exploration in neonates. Wertheimer (1961) also found that neonates oriented towards a sound presented in the light. This result was replicated by Alegria and Noirot (1978, 1980) and Turkewitz et al (1966). The result was partly replicated by Butterworth and Castillo (1976) although the head movements were contralateral to the sound source, and so could not be considered exploratory. Field, DiFranco, Dodwell and Muir (1979), Field et al (1980) and Muir and Field (1979) have also recently reported that infants up to three months of age will turn their heads towards a sound source. Further evidence of auditory-visual co-ordination comes from an experiment by Aronson and Rosenbloom (1971) in which audition and vision were put into conflict by dissociating the visual location of the mother's face from its auditorily specified location by means of two speakers. Infants less than two weeks of age were distressed by this dissociation indicating that they perceive within a common auditory-visual space - they expect voices to come from mouths.

Visual-manual co-ordination has also been cited as providing evidence of perceptual functioning as opposed to functioning within specific sensory terms. Bower, Broughton and Moore (1970 a, b, c) demonstrated that a fixated object was reached for by infants from six days old, with anticipatory hand-shaping occurring as early as seven days of age. Distinction between a 3-D object and a 2-dimensional representation has also been found (Bower, 1972; Bower, Dunkeld and Wishart, 1979). A more detailed analysis of this type of co-ordination will be discussed in a later chapter (Chapter 4). At present it is reported only to demonstrate the evidence for a seeming early inter-sensory co-ordination in the infant, one which later becomes dissociated (Bower, 1979 a, b, c).

Auditory-manual co-ordination has been much less studied. Wishart, Bower, and Dunkeld (1978) investigated the reaching behaviour of sighted babies to a noise-making object in the dark. The subjects involved were aged four to twelve months. They found a U-shaped function for successful reaching with auditory-manual co-ordination high at five months, disappearing around six months and then reappearing at about eleven months. Bower (1979c) argued that the decline represented differentiation of the senses in that a sound no longer had the potential to specify that an object could be seen and touched. A similar pattern of development is suggested by observations of blind babies (see e.g. Adelson and Fraiberg, 1974; 1976). Blind infants are late in reaching to a noise-making object. They will, however, track sound-making objects with unseeing eyes from an early age, a behaviour which later dies out. Freedman (1974) has reported that, early in life, the blind infant will also turn its eyes in the direction of a sound source. Moreover, Bower (1979a) has reported that they will engage in 'hand regard' with unseeing eyes at an early age, a behaviour which also disappears. Again this suggests that the information picked up by the young infant, whether blind or sighted, is truly amodal and not sensorily specific.

From the above review of only some of the developmental studies on the unity of the senses, it is clear that there are severe disagreements as to the nature and course of the development of intersensory co-ordination. Rather than examining all of the conflicting studies, auditory - visual co-ordination will be taken as a paradigm case which illustrates well some of the disagreements which have arisen. As indicated above, Wertheimer (1961, op. cit.) found visual search to a sound source, in the light, in a baby only ten minutes old. This infant showed consistent ipsilateral orientation in response to a lateral auditory stimulus. However, McGurk et al (1977, op. cit.) found no such directional head turning in infants up to eight days of age. On closer analysis, however, it is seen that the methodology they used ensured that it was unlikely they would obtain results consonant with Wertheimer's or with Aronson and Rosenbloom's (1971, op. cit.). In the McGurk study no attempt was made to equate the intensity of the sounds. Turkewitz et al (1966) have shown that orientation to auditory stimuli, like orientation to visual stimuli, depends on the intensity of the stimulus. If the stimulus is too intense then orientation in the opposite direction will occur. This concurs with the work of Butterworth and Castillo (1976) and can be seen as an adaptive response. A second experiment carried out by McGurk et al more directly attempted to replicate Wertheimer's study, with their results again being negative. Again it would appear that there was a methodological reason for the failure to replicate. The auditory stimuli were presented in such a position that a 90° eye movement was necessary for visual inspection. It is extremely unlikely that this movement would be obtained with auditory stimuli, as it is not obtained with visual stimuli (Alegria and Noirot, 1978, op. cit.; Harris and Macfarlane, 1974). Such studies point to the importance of noting the precise conditions of testing before evaluating behavioural data as evidence of presence or absence of early intersensory co-ordination. Special care in interpretation must be exercised when a non-response is all that is obtained.

THE PRACTICAL APPROACH TO THE PROBLEM

There is an alternative approach to intersensory substitution experiments, an approach that begins from practical rather than theoretical concerns. What can we do for an organism that has lost the use of a sense? In this field the lead has been taken by engineers rather than by psychologists. The idea that it is possible to provide artificially the essential features of information normally given by one sense through another sense was first suggested by Alexander Graham Bell (1900), the suggestion being to provide a radiophonic ear for the blind. Since then a number of devices have been designed by engineers which function by substituting information normally channelled through one sense with information through another sensory modality. White et al (1970), for example, attempted to reproduce the features of visual information by making the back of a blind subject function as the retina of the eye. Fish and his co-workers (Fish, 1971; 1972 a, b; 1975; 1976; Fish and Fish, 1976) provided two-dimensional information through audition. This device worked by transducing the images of two dimensional patterns and pictures into an auditory code through a series of tone bursts.

In the case of the deaf, the classic work on sensory substitution was carried out by von Békésy (1955; 1967). From experiments he began in 1927, he recognised that similar types of results were obtained in experiments performed with each sensory modality. He believed that there was a generality which connected vision, hearing, skin sensations, taste, and smell and that:

> "this interconnection made it possible to plan new experiments for one sense organ almost as a repetition of an experiment done with another."
>
> (von Békésy, 1967)

As a direct result of this work, a device was constructed which provided auditory information through the skin, with the skin of the arm simulating the function of the cochlea. Similarly, two microphones attached to the chest enabled subjects to localise 'sound' information outside the body by converting the sound to vibrations. Scott (1978) and Scott and De Filippo (1979) have coded auditory information by changing the "quality of sensation" rather than the locus of stimulation. This device was worn between the thumb and forefinger on the back of the hand. With it, their results showed that an improvement in accuracy of lip-reading could be gained.

BINAURAL SENSORY AIDS

The device used in this thesis was the Sonicguide, one of a number of binaural sensory aids, and was invented by Professor Leslie Kay of Canterbury University, New Zealand. The term "binaural sensory aid" was used by Kay (1973) as a generic term for a number of different sonar aids: the sonicguide used in the present series of studies is one of the later modifications to the design. Before discussing the two particular Sonicguides[1] used in the present studies, a general description will be given of the characteristics common to all binaural sensory aids. The specific information supplied and its limitations depend on the engineering parameters of the type of aid used. Discussion of the psychophysics involved will be left until discussion of the

---

1 Thanks are due to Wormald Vigilant, New Zealand, who supplied one of the Sonicguides used in these studies free of charge.

Sonicguide itself.

All binaural sensory aids utilise the principle of echo-location whereby sound is reflected by objects. When a soundwave encounters an object in its path, the wave may do one of two things depending on the size of the object: if the wave is larger than the object it will flow round it; if smaller, it will be reflected from the object with the angle of incidence being equal to the angle of reflection. If audible sound were used, this would mean that many objects would not provide echoes as the sound waves would simply flow around them. Ultrasonic sound was therefore used with these aids, since ultrasound enables echoes to be generated from much smaller objects than audible sound. The ultrasound produced continuously irradiates the environments, is reflected from objects in its path and is then converted to audible sound. The conversion from ultrasound to audible sound results in echoes being transmitted as pure tones. This is unlike the interference patterns of natural echoes which rely on interference of sound waves between the incident and reflected waves. (This point is discussed further on page 262 .) The ultrasound is produced by a single transducer located midway between and below two other transducers. The latter two transducers receive the ultrasound reflected from objects, convert it to audible sound, and then transmit it to the ears (one transducer feeding to the left ear, the other to the right ear). The signal-mix codes for distance from observer by changes in pitch, so that an object at maximum range gives a low pitch (i.e. low frequency echo note).

The distance code of a binaural sensory aid can be adjusted to suit different users and different purposes. The maximum range with the adult aid is about 6 metres when the frequency is 5400 Hertz. The distance to an object is therefore coded at about 900 Hz/m. i.e. for every metre increase or decrease in distance from the user there will be a concurrent increase or decrease in frequency of about 900 Hz. The use of the pitch to indicate distance stems from the observation that the source of a sound can be recognised from its timbre, with it being possible to discriminate several sounds heard simultaneously. Juurma (1970) points out that man is capable of distinguishing approximately 1,400 pitch steps and about 350 intensity steps. Therefore the number of tones possible to be discriminated is approximately 340,000. (It is also possible that the number of tones which can be discriminated unconsciously would be even larger). Kohler (1956) has emphasised that differential threshold values are more necessary for the perception of objects than stimulus threshold values obtained by audiometric measures. Consequently it is discrimination and perception of changes which is more important than the detection or non-detection of a particular sound. Kohler found that perception of obstacles (or "obstacle sense" as he called it) correlated with audio-metric variables only to the extent of 0.2. Kay (1978) indicates that for the greatest degree of object detection, the distance code should be adjusted to suit the needs of the user. This point will be returned to later.

Detection of more than one object in the field of the guide is more complex. Kay (1978) draws the analogy of resolving power in optics when discussing this problem. When two or more objects appear in the field he states that "there is nothing in the well established literature which enables us to determine the 'resolving power' of the system in auditory space". When two tones are presented simultaneously they are perceived as being separate only if the higher pitched tone is 40 per cent above the lower frequency tone. Other than this (i.e. when there is less difference in frequency than 40 per cent), a combination of the two tones is heard and the "two primary tones cannot be listened to separately i.e. attention cannot be shifted from one to the other" (Kay (1978)). Although it may be possible to say that more than one object is present, it is not possible to give their relative positions in space. This point will also be returned to later in discussing the sonicguide used in the present studies (see page 31).

The sensory aid is binaural, with the direction of audible sound being determined by the difference of amplitude of sound in one ear relative to the other. This difference in amplitude between the sound at the ears is used as the direction cue. The direction code is expressed by the interaural amplitude difference (I.A.D.) in decibels per degree azimuth angle. The estimated angle of an object from the user may vary from the actual angle of the object. In the midline there is no difference, but any deviation to the right or left results in differences between angle of the object as specified by the guide and the true angle of the object. This can be seen from Fig. 1.1. Kay suggests that for the purposes of adult mobility this "inherent physical limitation" need not present a problem, but that for developing infants the setting of the direction code is critically important.

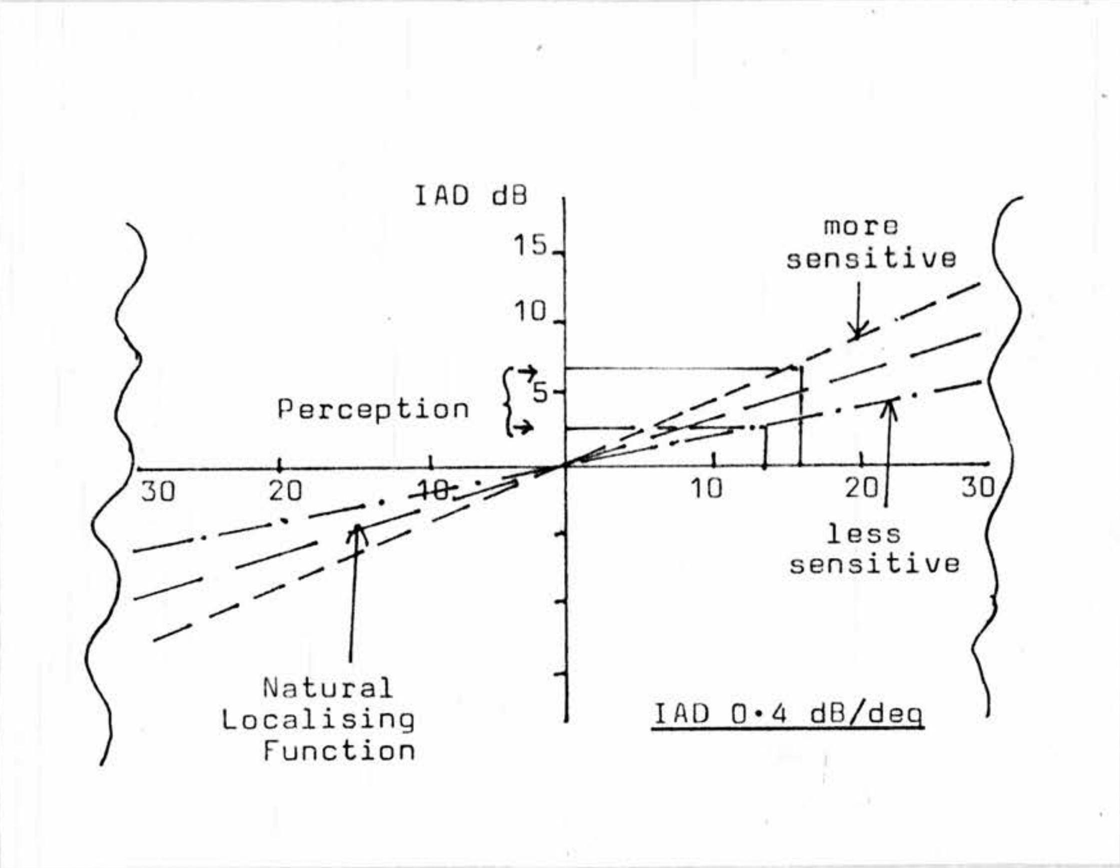


Fig. 1.1: Direction code of binaural sensory aid (after Kay, 1978)

The field of view of the aid is similar to a cone of angle varying from a few degrees up to 100^{o}, in reference to the perpendicular axis of the two transducers. A range of angles of field of view is therefore available, the designer choosing the most appropriate. The cone is, however, a fairly arbitrarily chosen index of the field of view. Signals may still be received from outside the cone and the signal intensity within the cone may vary with angle. The angle of the field is taken to refer to the angle at which the perceived sensitivity has reduced by 3dB relative to the midline. This can be more clearly seen from Fig. 1.2. The angle 0^{o} corresponds to straight ahead. It is seen that the transducer sensitivity is maximum at α degrees to the left or right. This angle is termed the 'splay angle' and is of importance when we consider the three dimensional field. In the vertical plane the sensitivity of the receiving transducers varies equally with the horizontal plane only when the vertical plane is in the direction of the splay angle. Variation in the I.A.D. direction cue therefore exists in planes other than the horizontal plane.

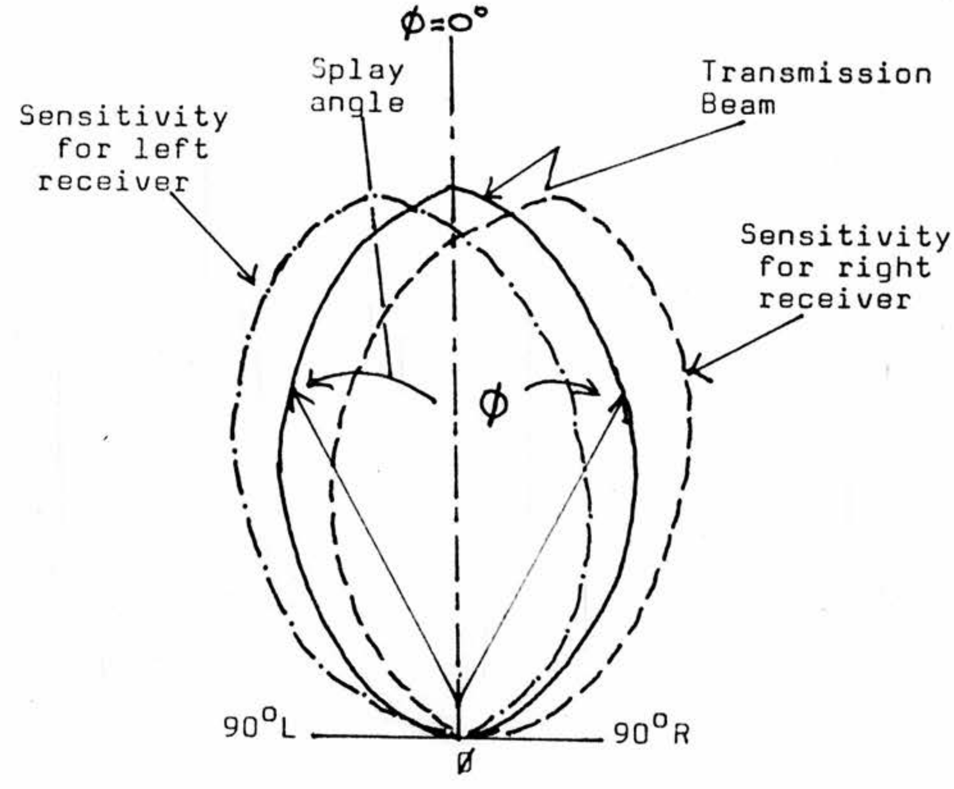


Fig. 1.2: Field plots for transmitter and receiver transducers (after Kay, 1978)

The range of the aid can also be varied. The intention behind the original aids was to provide information about the middle distance. Long range information, such as position of a road intersection in the distance or approach of traffic, was thought of as being within the capabilities of natural unaided hearing. The "middle distance", was defined as the distance from outstretched hand to about 6 metres. Kay (1974 a, b, c) and Strelow, Kay and Kay (1978, 1979) advocate a variety of aids, from 0.5 m. to 6 m. depending on user requirements. They suggest that the long range binaural aid is optimal for street travel and larger object identification. A short-range binaural aid is regarded by them as being suitable for perceptual-motor skills such as reaching, and is seen as the best all-round children's aid.

The Sonicguide

The type of sonicguide used in the present studies differs in a number of ways from the binaural sensory aid described above. These differences are not unimportant when we consider the psychophysical and the functional requirements of the developing blind infant. A great deal of controversy has arisen concerning the "ideal" type of guide to be used (Bower, 1977 a, b; Kay and Strelow, 1977). This controversy arises from the entirely different theoretical approaches of the original researchers - one with an engineering bias, the other with a background in infant psychology. As will be suggested later (see page 34), a basis in engineering would never have provided the idea that guide work with infants would show more promise than similar work with adults. An engineering background provides no information as to the psychological requirements of an intervention programme. Similarly, it will be argued that the specifications of a sonicguide for use with blind infants must take note of the observations of developmental psychologists. This type of analysis is evident in the work of Bower (1977 a). Modifications of the sonicguide were directed by theoretical ideas of development derived from work with normal infants. These modifications resulted in what Kay and Strelow describe as "Limitations" in the sonicguide used in the original Bower (1977 a) study. Some time is therefore necessary to draw a comparison between the sonicguide used here and by Bower, and the binaural sensory aid used by Kay. These differences are, in engineering terms, differences in the signal characteristics of the aids; in psychological terms they represent psychophysical and functional distinctions.

The sonicguide used in the studies is shown in Fig. 1.3 (see over). The whole device weighs approximately 15 ounces, which includes a four-ounce, rechargeable 12-volt battery. The guide consists of three parts: the frame, the lead, and the control box. In the centre of the frame are three circles of stainless steel gauze, each a half-inch in diameter. These protect the one transmitting and two receiving transducers. The lead contains the microcables which connect the frame with the control box. The control

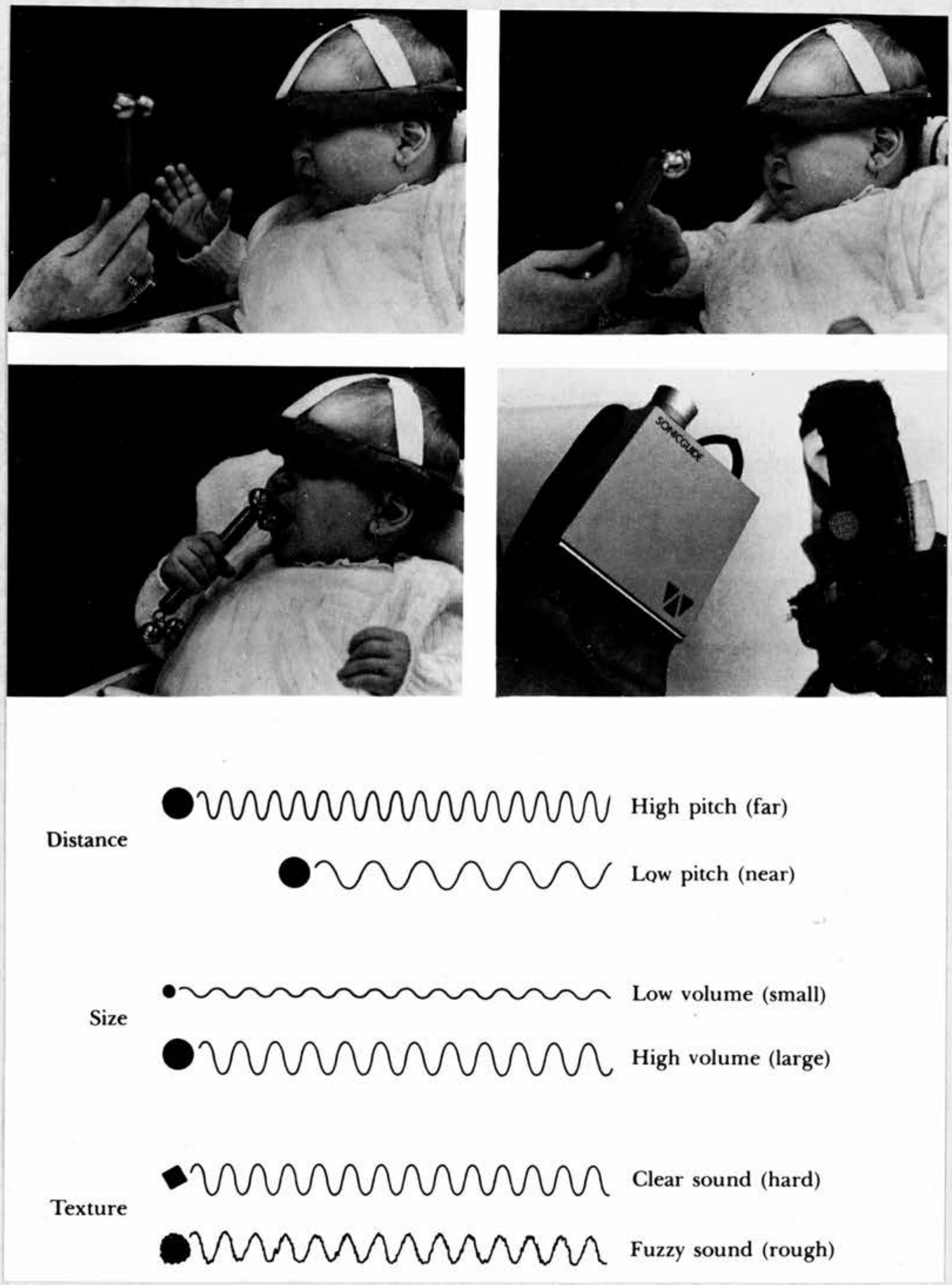


Fig. 1.3: The Sonicguide used in the present studies

box contains the circuitry and an on/off volume control knob.

General appearance: Certain practical problems have to be overcome when working with the guide with infants which are not met when working with older children and adults. A certain amount of discussion has been centred around the type of mounting used with the guide. With the adult aid, the transducers and ear-pieces are mounted on a spectable frame. This frame is cosmetically appealing, and Kay and Strelow have argued that cosmetic appearance in designs is important, and that effort should be made, when working with infants, to ensure such cosmetic appeal. Bower (1977 b) has replied that due to the immediacy of the requirements of early intervention, time is not available for the enhancement of the appearance of the guide. This does, however, ignore a point in favour of enhancing appearance of the infant guide. This concerns the attitude of the parents. Attempts must be made for the parents to accept that the guide may be of some benefit. This is not easy in the initial stages of discovery of the handicap - a point which is more fully discussed in Appendix I. If the parents are having difficulty in accepting that they have a blind baby, this difficulty may be exacerbated by them having to deal with a baby who has an ugly contraption on its head. Alienation may follow, both towards guide and baby plus guide; this may result in little or no interaction with the infant while wearing the guide, a process which will result in no obvious benefit of guide use. It would appear then that a balance should be struck between the amount of time spent on cosmetic improvement and delays in implementation of guide wearing.

Instead of a spectacle frame to carry the transducers and ear pieces a headband was used in the studies to be described. In the early studies, the headband was made of foam and plastic (see Fig. 1.3). This ensured that the guide remained on the user's head and in a constant position. This was necessary to ensure that an object in a fixed position provided a consistent signal as to distance and direction. In the studies to be reported with sighted infants, the guide was mounted on a piece of elasticated crepe with 'Velcro' attached. This enabled the guide to be used with a large range of head sizes, while providing consistent information across subjects as to distance and direction.

Volume: A further problem for research into infant guide use concerns the volume control of the guide. In nature, the bat is able to increase or decrease the ultrasonic pulses it emits for navigation, thereby enabling ambient environmental information to be picked up while time-sampling the ultrasonic information. Akin to this with the guide, the adult and young child can turn the volume control up or down so as not to block out the other available auditory information. The infant cannot do this for himself. It is therefore necessary to have the volume of the guide set at an optimum level. This may vary between sessions.

<u>Distance</u>: The carrier frequency or radiated frequency of the guide varies linearly - termed a sweep. Sweep time takes about ten times the duration for sound to travel to the maximum range and return. If the range is 1 metre then sweep time is 60 milliseconds. For continuous transmission sweeps have to be repeated every 60 ms.

Two sonicguides were used in these studies, one used less frequently than the other. The first, more frequently used guide had a range of 2 metres. The second had a range of 1 metre. Fig. 1.4 a shows the relation between distance and frequency for an object presented in the midline in the horizontal plane. The object used was a wooden block, dimensions 200 mm x 200 mm x 50 mm deep[2]. It will be seen that f varies linearly with distance. The particular value depends on the D code of the device. The linearity shown implies $f = kX$.

Differentiating with respect to time:

$$\frac{df}{dt} = k\,\frac{dX}{dt} = -\,k\,V$$

Dividing the equations:

$$f/\frac{df}{dt} = -\,X/V = -\,T_c$$

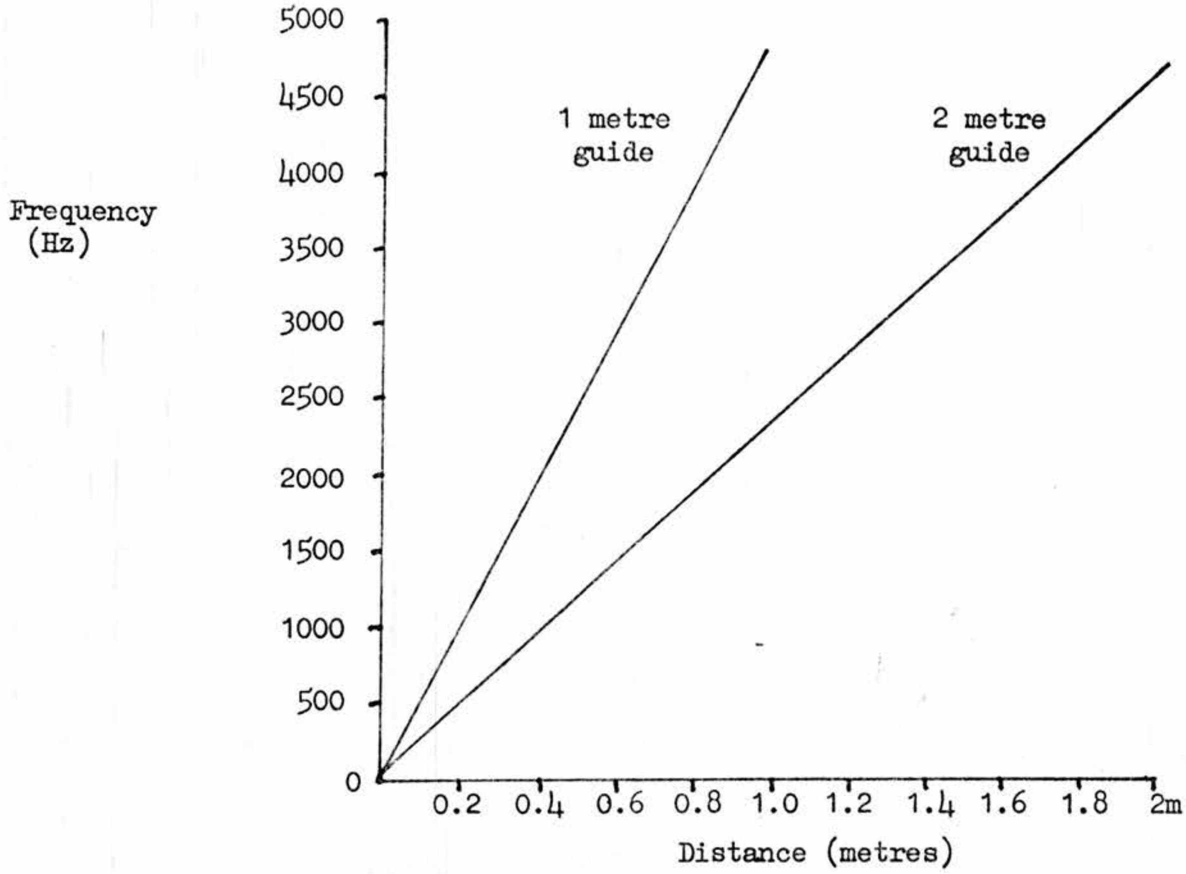
where T c = time to contact

$$\text{i.e. } T_c\left[\frac{df}{dt}/f\right] = -\,1$$

The resulting figure is plotted in Fig. 1.4 b. This invariant relationship, independent of the particular Distance code, will be returned to later (page 39).

---

2 This and the following results were obtained from tests carried out in a soundproof room measuring 4 m x 3 m x 3m. The room was totally empty apart from the test materials.



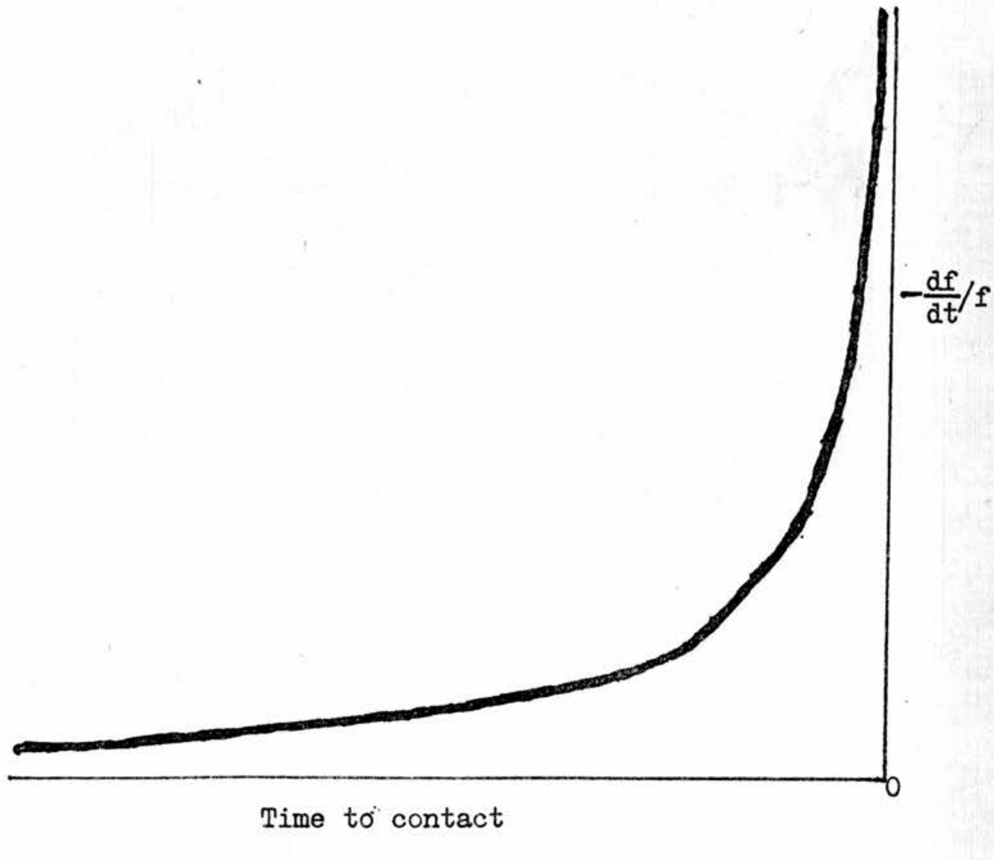


Figure 1.4 (a) Relation between frequency and distance for 1m and 2m guides.

(b) Frequency change plotted against time-to-contact.

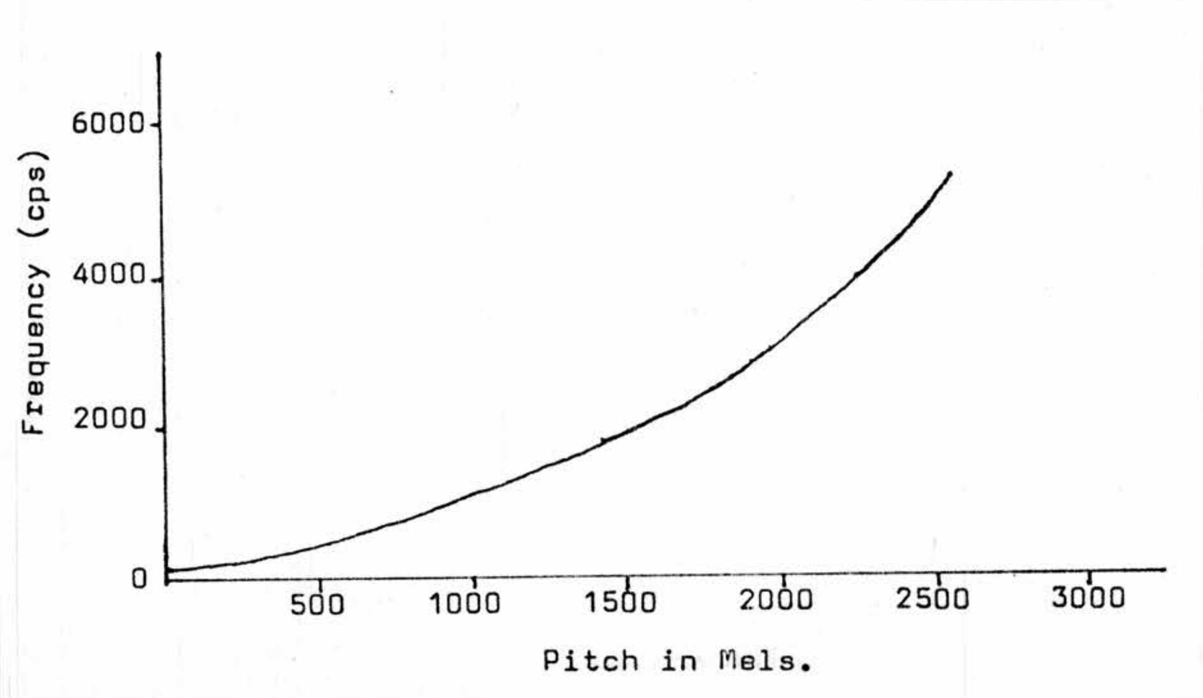


Fig. 1.5: Relation between frequency change and subjective pitch as measured in "Mels"

Fig. 1.5 shows the relation between frequency change and subjective pitch as measured in "mel" values (Licklider, 1950). From this, we can see that with the guide an approaching object produces the same expansion pattern for the ear as the expansion pattern produced at the retina by an approaching object. The information for time to contact of the object is invariant across both sensory modalities of vision and touch. The sonicguide information specifying distance conforms then to the same expansion pattern as that for vision. That auditory information about distance and distance change can be best picked up if presented in this way has been shown by the work of Rice and Feinstein (1965) and Kellogg (1962). Kellogg showed that in experiments on the perception of distance utilising natural self-produced echoes, blind subjects' results conformed to these standard psychophysical curves. These curves followed the typical pattern of curves obtained in psychophysical measures of sensitivity in the visual, auditory, kinaesthetic and other sensory modalities. Kellogg found that the average threshold fraction for the blind utilising echoes for depth perception was in fact better than the average obtained for monocular depth perception with sighted subjects. His subjects (who were not congenitally blind) were, however, allowed to use head movements, whereas subjects in monocular depth perception experiments are not allowed to do so. There seems, therefore, to be a good theoretical basis for presenting distance information with the sonicguide in this way.

An observation which has often been made about the distance specification of the sonicguide, and binaural sensory aids in general, concerns its relation to pitch. As can be seen in Fig. 1.4 a pitch increases as the object is further away. It has been pointed out that it would be more ecologically valid if the pitch were to decrease with increasing distance from the user. Kay (1966), in a reply to Broadbent, has indicated that the engineering requirements necessary to make sonicguide information equivalent to natural distance information, as specified by audible objects, are considerable. He accepts that this means an increase in training time required for adult guide users.

Size: Size differences are specified by differences in amplitude. A larger object produces a signal which is relatively louder than a smaller object. This relation is seen in Fig. 1.6

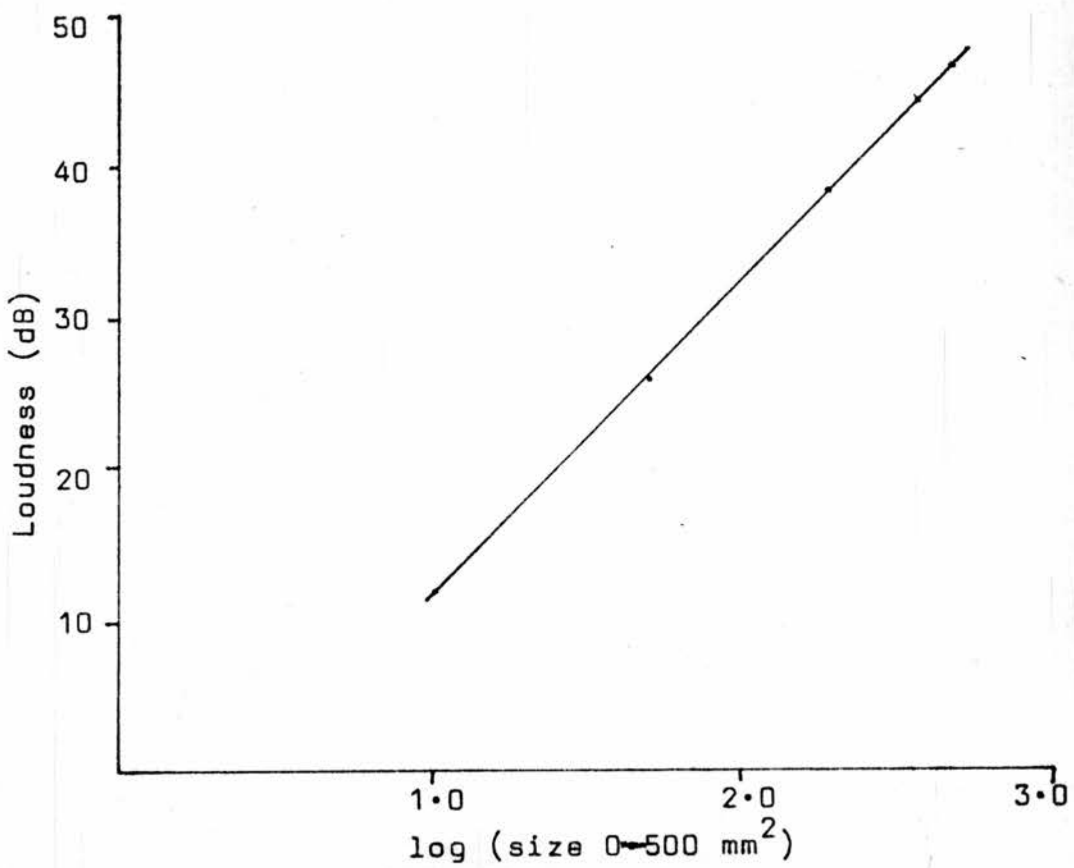


Fig. 1.6: Relation between size of an object and amplitude change (in Decibels)

Squares of wood of sizes ranging from 500 mm^2 to 50 mm^2 were presented at a range of 1 metre from the guide. (The depth of each object was constant at 50 mm). The amplitude changes obtained were converted to Decibels from oscilloscope readings using the formula:

$$dB = 20 \log \frac{\text{obtained voltage}}{\text{reference voltage}}$$

(where reference voltage is 0.2 V with no object present)

The use of natural echoes for size discrimination was also studied by Kellogg (1962). Here too he found that blind subjects demonstrated considerable discriminative ability. Again size is a property of objects which can be translated without reference to modality; it can be picked up by vision, audition or touch.

Direction: The direction of objects is also given by the guide, like the binaural sensory aid, in terms of the inter-aural amptitude difference (I.A.D.). The I.A.D. of the guide is 0.4 (expressed in terms of decibels per degree azimuth angle) and varies from that prescribed by Kay as the optimum at 0.3 (dB per = degree azimuth); ideally "the estimated angle arising from the localisation sensation should be the same as the actual angle" (Kay, 1978). In a different paper, Strelow, Kay and Kay (1978) quote a study by Rowell et al (1970) as showing that the selection of an I.A.D. of 0.3 is "typical of the localisation function such that objects would be sensed in their true direction by the wearer of an aid". The study quoted, however, showed that the selection of an I.A.D. was extremely complex. Between-subject differences were gross, as too were within-subject differences. The latter existed for different frequencies and intensities of the signal. Therefore the choice of I.A.D. must be averaged over a number of situations. Kay and Strelow (1977) point out that the choice of 0.4 I.A.D. introduces a limitation which may seriously affect the subject's ability to correctly identify the direction of sounds. The characteristics of ultrasound are such that the difference in time of arrival at the two ears specifying an off-centre object is augmented. This results in the object as specified by the guide being perceived as being in a slightly different position from that which would be specified if the object itself were emitting the sound. There is no discrepancy in perceived and true position for straight-ahead objects. Whether or not this is a "limitation" in design is discussed more fully in Appendix II.

Texture: Texture has also been shown to be a property of an object which can be presented through any modality. Kellogg (1962), for instance, showed that blind adults can learn to use natural echoes to discriminate materials made from velvet and denim, or cloth from glass for example.

Textural differences of objects as specified by the guide are perceived as differences in clarity of the signal. A fuzzy signal represents something soft, such as wood or foam; a sharp clear signal represents something hard like metal, glass or wood. Examples of textural differences can be seen in Fig. 1.7. In this case objects of a certain size, 100 mm^2, and at a fixed distance of 0.5 metre were presented in the midline of the guide. To demonstrate the differences in signal arising from textural variation, a wooden object, a foam object and a fluffy duck were used. (The fluffy duck was the stimulus object used in the reaching experiments to be reported later - see Chapters 4 and 5).

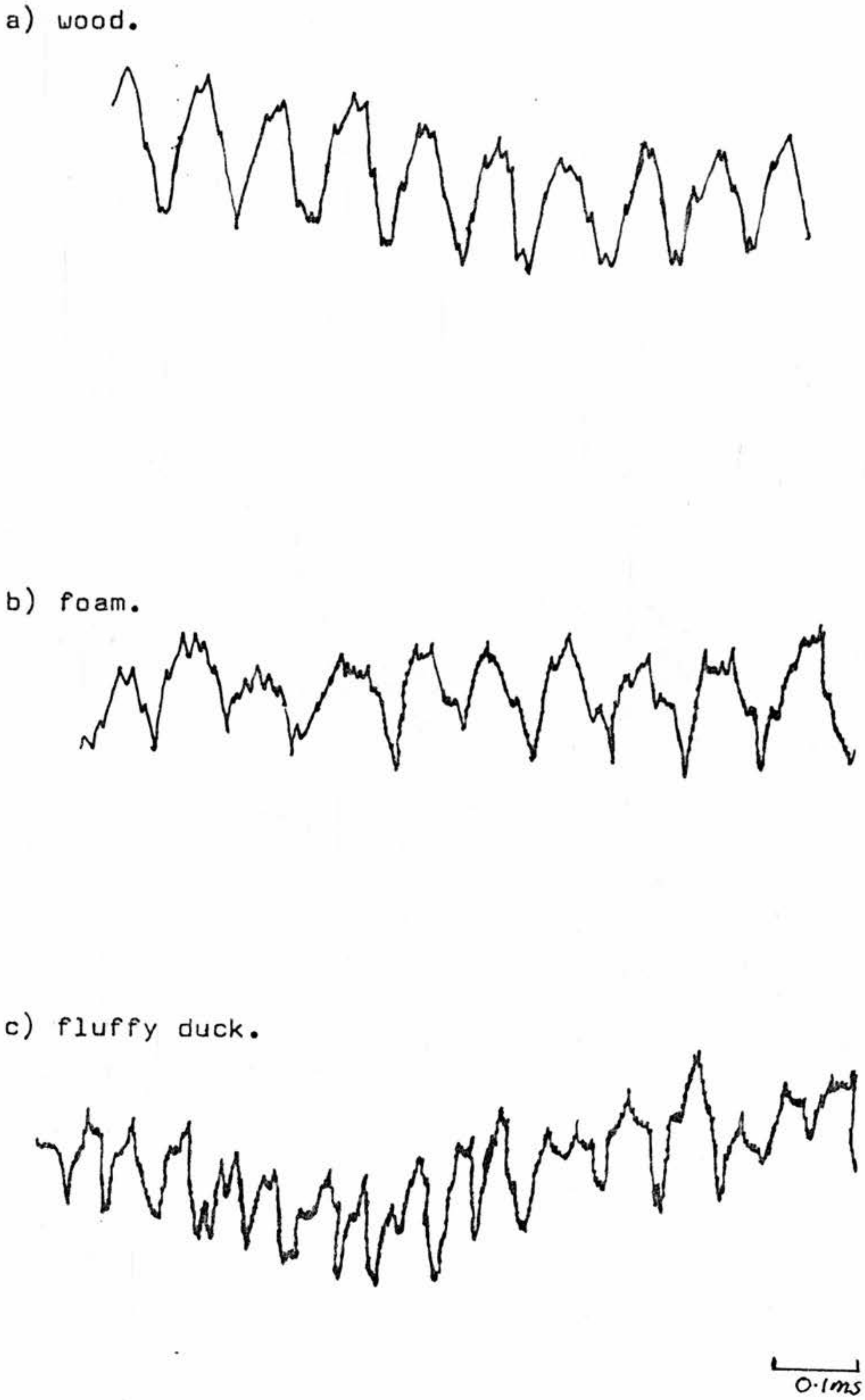


Fig 1.7: Differences in texture of objects and corresponding oscilloscope readings for (a) wood; (b) foam; (c) fluffy duck

Shape: The discrimination of shape received only passing attention by Kay and his colleagues. The work of Kellogg, Rice and Feinstein, and Kohler also concentrated on distance, size and texture and virtually ignored shape discrimination; shape discrimination received attention only with reference to different sizes of rectangles. Perception of shape through vision is well studied in adults. However, the perception of shape through audition is somewhat different from the other properties of objects we have looked at thus far. With audible sound produced by noise-making objects, no cues exist as to the shape of the object emitting the noise. Speech, for instance, could be coming from a person, a television or a radio. The quack of a duck could be coming from a large duck or a small duck or not from a duck at all. It is only through experiencing a duck quacking that we come to associate what shape to expect when we hear the quacking in the future. The sound from audible objects is therefore not a source of invariant information. In the adult world objects which emit noises are checked out visually to discover shape. This is not accessible to the blind population who must engage in tactual exploration.

This argument does not, however, apply to echoic information about the shape of objects. Objects have a finite size and vary in their regularity versus irregularity of shape. Multiple echoes can therefore be received by the sonicguide from reflecting discontinuities of an object. Each discontinuity would produce its own tone. An example of this can be seen in Fig. 1.8 (see over). In this case objects made

a) cube.

b) sphere.

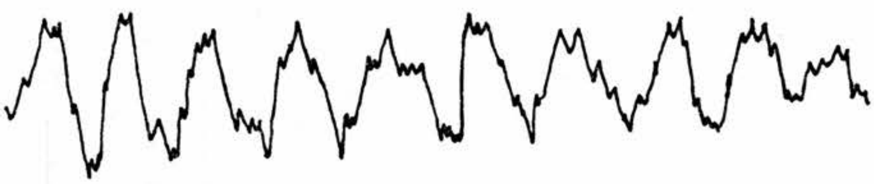


Fig 1.8: Differences in shape of objects and corresponding oscilloscope readings for (a) cube; (b) sphere

of steel 50 mm^3 were presented at a constant distance from the guide - 0.5 m. The objects were a cube and a sphere. The characteristic echoes of these objects can be seen in the **figure** and are easily distinguishable. Subjects would therefore be able to pick up these differences in sound character, and be given information as to the shape of objects in the field of the guide.

<u>Field of view</u>: Kay (1978) emphasises that considerable thought should be given to the choice of a field of view. He points out that the possibilities available for field of view, from a few degrees up to 100 degrees, may vary with the situation, with that designed as suitable for one task being unsuitable for another. The field of view chosen for the sonicguide used in these studies was a cone of 80° (as previously shown in Fig. 1.2). This provides a sufficient acuity for central fixation as well as providing information about peripheral objects which the subject can attend to.

<u>Movement</u>: Thus far we have been concerned with stationary objects. What happens when objects move to or from the guide? When a sounding object moves towards (or away from) another object the velocity of the sounding object is added to (or subtracted from) the velocity of the sound, resulting in change of the frequency of the sound received by the listener. As far as the listener is concerned there is a change in pitch. This is known as the Doppler effect.

Kay (1978) has posited that Doppler shifts do not appear to be a problem with adult aid users. Although Kay does not provide a reason for this, it is possible that the guide is used in a manner similar to the two functions of vision suggested by Thomson (1977). The first function is to provide ambient information which can be sampled while walking, running or jumping. It does not have to be continually used to check the exact layout of objects in front of the person. As the observer approaches objects he can begin to focus attention upon them, either to avoid them if they are obstacles, or perhaps to manipulate or inspect them. This is seen as the second functional use of vision. This would fit in with Kay's observations of adults using the guide for mobility purposes. As they approach objects they decelerate which results in less distortion due to Doppler shifts. It is then that they attend more to the information specifying approach to objects. Kay has suggested that the Doppler effect would cause problems for an infant guide user. This possibility is discussed more fully in Appendix II.

<u>Perception of more than one object</u>: Recognition of more than one object in the field of the guide involves more complex echo-location. A return to the discussion on Page 15 is necessary. It will be recalled that Kay (1973) drew the analogy of resolving power in optics in the perception of multiple objects with the guide. If

> "two or more objects simultaneously appear in the viewing field, there is nothing in the well-established literature which enables us to determine the 'resolving power' of the system in auditory space."
>
> (Kay, 1978 p. 9)

It is necessary, he points out, that if two tones are to be distinguished, then one must be 40 per cent higher in frequency than the other. This statement is based on work done by Do and Kay (1977). In this study two tones were presented simultaneously through headphones. They pointed out that although it is possible for subjects to say that two or more tones are present, their relative positions cannot be determined. This study is, however, only relevant to a static organism; what we are concerned with is a dynamic organism picking up change in signals. Relevant to this is the work of Kohler (1956). He found that "obstacle sense" or the perception of obstacles at a distance did not depend on straightforward audiometric variables. He found that a correlation as low as 0.2 was obtained between audiometric variables and discrimination of the presence of more than one object. It is the differential values he found to be important, and, with change of information being picked up, it is possible for the adult to detect and discriminate 340,000 tones (Juurma, 1970). Perception of multiple objects in the field of the guide would not therefore seem to pose the problem for subjects which Kay proposes.

ASSESSMENT OF SONICGUIDE USE

(a) Use by blind adults

Despite the sophisticated engineering, the sonicguide has proved to be a disappointment in use with adults. Kay (1974) reported a major evaluation study of the original Binaural Sensory Aid. This was the report of a large-scale study of adult guide users who used the guide on a long-term basis. The study consisted of filmed evidence of users of the device and of interpretations of replies sent to 96 blind adult users and their 24 teachers. The blind users were aged between 18 and 55, with normal hearing. In addition all were totally blind, although it is not reported whether they were congenitally blind. Kay reports that training required up to 70 hours, with "most subjects grasping the concept within about 3-4 weeks" (Kay, 1974).

The total training period varied from several weeks up to six months.

The adults in this study seemed to have great difficulty in making effective use of the information provided by the guide. In particular they proved to be unable to discriminate edges while wearing the guide; this meant that they could not use guide for locomotion, nor could they detect apertures, e.g. open doors. (A discussion of the psychophysics involved in these problems is given above.) This study emphasises the slow gradual build-up which characterises adult training, with laborious re-learning being required before appropriate responses can be transferred to new stimulus inputs. Kay also emphasises the necessity, even with long-term users, of making maximum use of a priori information, such as the knowledge that when the subject comes to a road intersection, the signal received is most likely coding for a traffic light as opposed to anything else.

Given that the adults studied found the device difficult to use, what then should an infant be able to do with such a machine? According to nativists, the infant should do no better than an adult user. According to empiricists, the infant should do less well than an adult subject. On both of these accounts, therefore, there would be little point in attempting intervention with infant subjects. On a differentiation model, however, the infant might actually be expected to do better than adult users. Since the guide depends on the detection of equivalent information through audition to that which is normally presented through vision, it follows that most effective use should occur before differentiation of the senses has occurred. A study by Bower, Watson and Umansky in 1974 was initiated to examine this possibility.

(b) A case study of infant guide use

The infant studied by Bower, Watson and Umansky was born ten weeks premature and was found to have been blinded by retrolental fibroplasia at birth. At six weeks of age (corrected for prematurity), DD showed an ability to use echoes of spontaneously produced sharp, clicking noises to locate objects, turning to 'look' at them. At 16 weeks, the infant was provided with the Sonicguide and seen thereafter once per week (Bower, 1977 a, b; Bower, Watson and Umansky, 1979). Bower (1977 c) describes the first session with the guide as follows:

> "His initial response can only be described as total stilling of movement. . . An object was introduced and moved slowly to and from the baby's face. It was moved close enough to tap the baby on the nose. On the fourth presentation convergence movements of the eyes were seen. . . On the seventh presentation the baby interposed his hands between face and object. . .
>
> (Bower, 1977 c)

Radial tracking was obtained, with head and eyes following the lateral movement of an object. A peek-a-boo game was engaged in. Later 'hand regard' was obtained, reaching and grasping became more successful and a preference emerged for a particular toy presented soundlessly in the field of the guide. Later still, stranger fear was shown to one of the experimenters, a response seemingly based on the distinctive echo signal produced by this person's spectacles. Placing behaviour (Walters and Walk, 1974) was shown in a variety of tasks. The infant also showed an ability to utilise the complex information produced by the guide to spatially locate multiple objects. It seemed, in short, that the infant was able to make good and effective use of the spatial information supplied by the guide. When compared against the developmental norms for blind or sighted infants (e.g. Fraiberg, 1968; 1975; 1977), DD's development was closer to that of a sighted than of a blind baby.

Implications: The study described above, while supporting differentiation theory, raised problems for that theory, indeed for any then extant theory of perceptual development. The main problem is how the infant could respond so rapidly to sonicguide information. For instance, Bower (1977 c) describes the infant as engaging in a peek-a-boo game. In this game, the infant would alternately bring his mother into and out of the field of the guide, a behaviour that led to wide smiles from the baby. Since the sonicguide is a man-made artefact, it could not possibly benefit from an evolutionary history; there is no way that evolution could have prepared the infant with the ability to extract meaningful information from the signals produced. To get the glimmerings of an answer, it is necessary to look at a radical innovation of recent years in theories of perception, the hypothesis that perception is a function of information rather than of energy.

Several sets of investigators have recently made strong attacks on the doctrine of specific nerve energies, denying that perception is an energy based phenomenon. For example, Michotte (1963) and his colleagues suggested that events may be perceived which have no corresponding physical stimulus. Consider an experiment which should lead subjects to detect compression. In this, one object (A) moves up against a stationary object (B). When the leading edge of A reaches B, its trailing edge continues moving, therefore A grows shorter along its path of movement.

Subjects did not report compression, instead that A had moved behind B. A second set of experiments showed that if, with no other object present, A goes through the same process as above, subject's impression is that of a slit opening in the background in which the object is 'swallowed up'. The third type of experiment involves the 'Tunnel Effect'. In this case A disappears behind one edge of B and reappears at the other. If the time taken for this to happen is greater than that necessary for A's travel through B at its previous constant velocity, the subjective impression is that the object halts inside the tunnel. Michotte coined the term 'amodal' for this kind of perception. He suggested from these cases that perception is direct, and does not require specific sensory correlates.

Another who has denied that sensory inputs are the basis of perception is J.J. Gibson (1950, 1966). Afferent inputs through the senses are not, he believes, the building blocks of perception. His theory of information pick-up stresses ecological rather than physical acoustics and ecological optics rather than physical optics. Information about the world is not carried in discrete senses and sensations, but instead invariants in the 'stimulus energy' specify the world. In perceiving, the perceptual system extracts invariants from the flux of this stimulus energy. These invariants are without reference to specific sensory modality and can be presented in any modality. They are, therefore, 'higher-order'.

The term 'higher-order' has always caused problems. An example from Bower may help to clarify the sense in which the term is used here. The example is one of the perception of radial direction (Bower, 1981). Humans can locate the position of a sound source, despite there being no right and left within the ear. This ability is due to the fact that we have two ears. Radial position can be detected by symmetry versus asymmetry in stimulation. With a sound which is straight ahead there is no difference in stimulation at the two ears. Sound waves arrive at the left ear at the same time as arriving at the right ear. If the sound source moves to the right of midline then an asymmetry in stimulation is introduced. Sound waves arrive at the right ear before arriving at the left ear. There is thus a difference in time of arrival (as well as phase and intensity difference) of sound at the two ears. This symmetry/asymmetry of stimulation is, however, a higher-order property which can be transmitted through any sensory modality. A similar mechanism is involved in olfactory localisation, which in this case relies on symmetry versus asymmetry of stimulation in the (two) nostrils. Von Békésy (1967) has shown that position can be detected through the skin of the arm through asymmetry of stimulation.

Another example of a higher-order variable is the so-called optical expansion pattern. Lee (1974) and Bower (1979 d) have shown that the visual properties of an approaching object produce the type of retinal expansion pattern seen in Fig. 1.9.

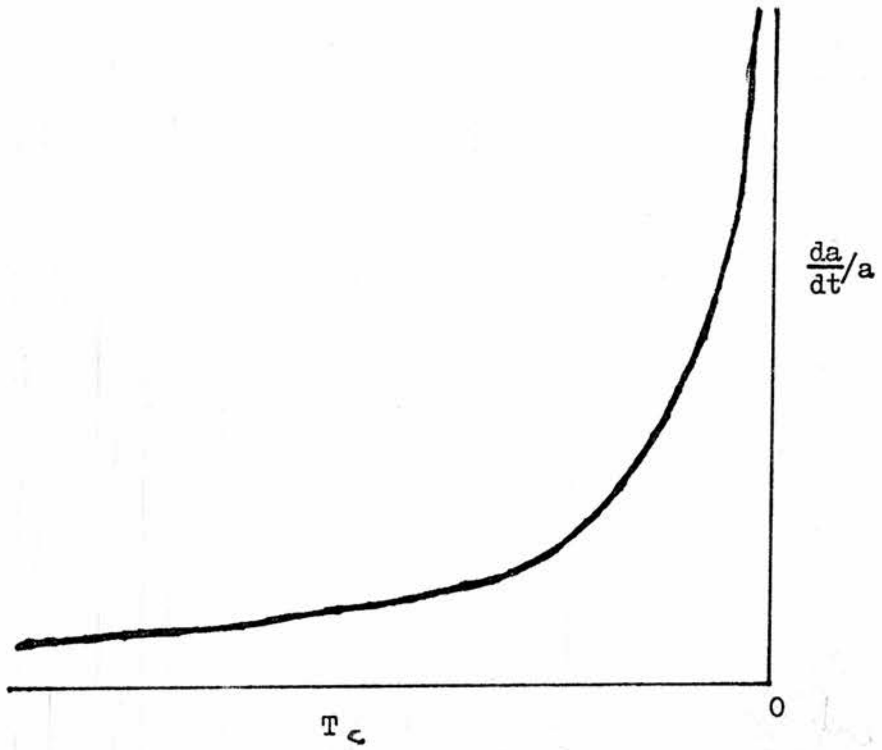


Fig. 1.9: Optical expansion pattern for an approaching object, where "a" refers to area of retinal image.

Such a pattern can be represented through any modality, with reference to any physical parameter of stimulation. If information is being picked up amodally then the organism should be able to use that information regardless of the sensory modality by which it is picked up. Bower has argued that it is just such higher order variables that the young infant responds to. Indeed he has argued that they can respond to nothing else. On this view evolution has provided us with a perceptual system to detect higher-order variables, regardless of the energy flow that carries them.

While this hypothesis accounts for the rapidity of use of the guide by the infant, it does not account for the slowness of use by adults. This is a particular problem for Bower (1979 b) who, in some publications at least, describes development as a process of differentiation without loss. This description stands in contrast to Werner (1948) and Bower himself (Bower, 1977) who described development as a process as a process of differentiation with loss. What this distinction means is that, for Bower, no absolute loss of guide use should occur. Subjects of all ages should be able to use the guide, although the extent to which use could be established would be dependent on the amount of specification that had occured in that sensory modality. For Werner, no use of the guide should be possible as there would be no dimension along which sensory reintegration could occur. The amodal distal information presented by the guide could not, in this view, be used by the subject. As sensory differentiation had occurred, the signals of the guide would be modality-specific, and have no informational value.

Indeed there is an alternative hypothesis that would undercut the whole problem, namely that infants <u>learn</u> more rapidly than adults or older children (Lipsitt, 1969). While possible, this view, if correct, would have drastic consequences for the study of perceptual development. If correct, the rapidity of the learning would call into question almost all of the experiments which have been carried out to establish the innateness of a particular perceptual structure, the very experiments used to buttress differentiation theory. With the exception of Wertheimer's studies, none of the infants used were strictly speaking newborns.

A sophisticated version of differentiation theory combining it with traditional empiricist views has been proposed by Gibson and Spelke (1981). In this account, they argue that the infant can detect higher-order variables in the stimulus flux to each sensory modality. It should be noted that their use of the term 'higher-order' variables is not the same as that described above. In their view information such as periodicity over time would be detected by eye and by ear. By comparing these periodicities, the infant comes to learn or associate that a seen event and a heard event are two aspects of the same event. An example of this view can be seen in the research of a number of workers in what has come to be known as the 'Spelke paradigm' (Bahrick, 1980). In attempts to discover the nature of those higher-order variables detected by infants, a fixation-preference and search paradigm has been adopted (Bahrick, 1980; Menten and Cohen, 1979; Spelke, 1976; 1978 a, b; 1979; Spelke and Owsley, 1979). Two sound motion pictures are typically presented simultaneously and fixation-preference measured. An auditory event consonant with one of the films and disconsonant with the other is played. For example, Bahrick (1980) presented two films of marbles rolling down a tube, with the sound track being appropriate to one but not to the other film. These workers argue that if infants are sensitive to invariants like temporal structure then they should prefer to look at the consonant, 'intermodal' event. Infants of 4 months of age were found to prefer such an intermodal event.

One last point should perhaps be made. It could be suggested that results of the Bower, Watson and Umansky study might be artefactual. The infant was after all seen on a once or twice weekly schedule by two psychologists and a pediatrician. No normally developing infant receives this amount of attention and stimulation from "infantologists". While this could not account for the results of the first session, that first session recorded only a few responses from a single infant, hardly enough on which to erect a large scale theoretical edifice, much less a large scale intervention programme.

AIMS OF THESIS AND JUSTIFICATIONS FOR METHODOLOGY USED

It was to try to resolve at least some of these issues that this thesis was begun. The aims were to discover
(1) whether or not humans of any age can use the sonicguide;
(2) and, if so, how;
(3) whether or not there are age differences;
(4) and, if so, what the source of these age differences is.
The aim was to answer the basic theoretical issues raised above and, in addition, to perhaps elaborate a theory of practical intervention.

In the research to be reported, two strategies were employed. One was to investigate the use of the guide by sighted subjects of various ages with whom blindness was simulated. The second was to investigate the use of the guide by blind subjects. In isolation a great deal can be learned from either approach. In studying blind infants, for example, theoretical predictions can be tested, while at the same time practical implications can be drawn. However, there are certain costs involved in this type of research, costs which are elaborated in Appendix I. Mainly these costs are concerned with the problems involved in the adoption of an over-experimental procedure with blind infants. These ethical considerations required that more detailed analysis using various experimental controls be carried out with a sighted sample of subjects with whom blindness was simulated.

In working with blind infants there was an additional problem involving the type of research design to be employed. There are four major types of research design that could be employed in investigating use of the guide by blind infants. The first is to carry out cross-sectional or single visit research in the infant's own home. There are two main problems associated with this design. Firstly, it does not allow for experimental control in standardisation of stimulus presentation. Secondly, there is the possible interfering factor on performance of the infant's affective state at the time of the visit. The second type of design involves one-off visits to the lab. While having the advantage of allowing total control over the surroundings in which the guide is to be used, this is in fact the weakest design. It not only involves the interference of affective state but it also presents the infant with a strange environment; an additional disadvantage of this approach arises from the fact that the parents often do not know how to implement anything they may observe in the lab. The third, slightly stronger, technique is to employ a longitudinal design (Wohlwill, 1973) with lab visits. This goes some way to discounting the effect of the infant's state on performance but still suffers from the problem of the parents extrapolating from what occurs in the lab to their own home. The fourth technique, and the strongest in isolation, is a longitudinal study in the child's own home. This is logistically the most difficult to carry out. In the studies to be reported here with blind infants, all four of these techniques were employed to various degrees. Where appropriate these are elaborated upon in the main text and in Appendix I. As indicated above, problems which meant a compromise in methodological rigour when working with blind subjects required that studies be carried out with sighted subjects. These were of two types: cross-sectional and longitudinal lab visits.

The age range selected for study was large. This necessarily raised problems of two kinds. Firstly, in how, for instance, one compares the performance of a university student with that of a neonate. Secondly, within infancy itself, there is considerable disagreement over what performance might be expected under normal circumstances on certain tasks, much less in the artificial conditions of the Sonicguide. The specific problems are discussed in the relevant chapters.

CHAPTER 2 - A CROSS-SECTIONAL SONICGUIDE STUDY OF THE BLIND[1]

INTRODUCTION

The studies of the blind using the Sonicguide to be reported in this and the following chapter were either cross-sectional or longitudinal. Each type of study addresses different problems, although a degree of overlap exists. The second category, the longitudinal studies, will be dealt with in the next chapter and address the practical problem of whether prolonged sonicguide use can alleviate the plight of the blind child. It seemed possible that such studies might also provide insights into the relative merits of the three conflicting theories of development outlined in Chapter 1. It was hoped that the first, cross-sectional category of study would provide information on the extent to which subjects of various ages can use the Sonicguide. In addition, it was expected that a more precise understanding of the nature and limitations of intersensory substitutability at different points in development would emerge. It was further hoped that this type of study would be valuable in solving a number of straightforward practical problems, mostly to do with the mounting of the guide.

---

1 The content of the studies reported in this and the next chapter are presented in Aitken and Bower (1981 a, 1981 b). These papers have been submitted to the Journal of Visual Impairment and Blindness and to the Journal of Experimental Child Psychology respectively.

SUBJECTS:

The specific case histories of each subject are described below. However, there are several factors common to all subjects. Firstly, all of the infants were congenitally blind to a greater or lesser degree. Accurate diagnosis of total blindness has proved to be more difficult than might be expected. The limitations of electrophysiological techniques are discussed in Appendix III. In brief however, there does not seem to be a simple linear relationship between degree of blindness as established by electrophysiological techniques and degree of cognitive lesions arising therefrom. Instead it would appear that even a very small amount of sight, small enough to be undetectable by electrophysiological methods, can be enough to ensure that development will proceed more along the lines of the sighted infant than of the blind infant. Therefore, wherever necessary (i.e. excluding such cases as bilateral anophthalmia), a behavioural assessment of infants reported to be totally blind was also carried out in order to establish whether or not there was in fact any degree of functional vision present.

None of the subjects was locally based, other than the school-age children who were recruited from the local blind school. This meant that the subjects had made trips to us or we had made trips to them, trips averaging 400 miles. In the first case, which was the more common, baby and parents were necessarily disturbed by the travel and associated difficulties. The second case, while having the advantage that the infant is seen in his own environment has the disadvantage of test conditions being less well controlled.

METHODOLOGY:

All of the parents involved were dedicated parents who, quite reasonably, would have resented any obviously over-experimental attack on their child. Their degree of protectiveness varied from, at the one extreme, the parents who requested us not to speak in the presence of their baby, to the parents who slapped their baby when he tried to remove the guide. The potential influence of the parent on the outcome of any intervention attempt with their child is clearly great. Because of this, impressions of the attitude of the parents in the testing situation will also be reported for each infant.

For several reasons, a clinical approach to testing was adopted, with video recording being taken of every session. It was felt that any attempt at a rigid testing procedure could adversely affect the results obtained, with no rapport being obtained between tester and subject. In addition, there was the possibility that the parents would see the assessment as being over-experimental and terminate the sessions too early. Sessions lasted from a few hours up to three days depending on the amount of time available with each subject.

CLASSES OF BEHAVIOURS STUDIED:

The infants covered in this study renged from 4 to 25 months in age; children between 4 and 11 years were also studied. Because of this, the range of behaviours it would have been possible to investigate was very large. The total range of behaviours actually looked at was indeed large, partly because it was subject generated. However, the classes of behaviours looked at were constrained by one over-riding factor - the necessity that the behaviour to be investigated distinguish clearly between congenitally blind and sighted subjects. This distinction could be qualitative or quantitative in nature. A qualitative difference would be when a behaviour seen to emerge in the sighted either does not appear in the blind infant or appears in a different form. A quantitative difference would be when a behaviour showed a different frequency between the two populations. Consequently, the following classes of behaviour were chosen to be looked at in detail: 1. responses to approaching objects; 2. social interaction games; 3. tracking; 4. reaching; 5. placing; 6. object concept; 7. locomotion. Not all of these could be investigated with every child in the cross-sectional study, due mainly to time constraints.

1. Responses to Approaching Objects: Defensive responses to approaching objects have been reported in sighted infants as young as one week of age (Bower, Broughton and Moore, 1970 b). The response consists of: (a) widening of the eyes; (b) head retraction and (c) hands being interposed between face and objects. Ball and Tronick (1971) showed that this response only occurs when the object is approaching on a hit path - objects approaching on a path that would miss the infant do not elicit the response. It is also essential that the infant be in a semi-upright position if the response is to be elicited.

These experiments suggest that neonates can perceive position and change of position in three dimensions. This claim was contested by Yonas et al (1977) who argued that the infants were not picking up three-dimensional change but that the response was due to the infant fixating and following the top contour of the approaching object. The top contour rises as the object approaches and, as a result, the infant's head falls back and his arms are raised because of the over-balancing. In answer to this study, Dunkeld and Bower (1980) presented infants with an approaching object associated with a falling contour, and a second display which specified vertical expansion and contraction of a stationary object. Yonas's prediction that the response of backwards head pressure would be greatest when the top edges of both presentations were at maximum expansion was not borne out. Instead, greatest head retraction occurred when an approaching object was associated with a falling contour. This confirms the evidence for the existence of defensive responses to approaching objects in neonates.

If defensive responses to approaching objects could be elicited while using the guide, it would be a clear indication of the pick-up by the infant of three-dimensional information concerning distance and change of distance. A distinction must be drawn though, between a response elicited after an object has approached the infant <u>without touching him</u> and a response elicited by an approach ending in <u>contact with</u> the infant. In the former case we would have good evidence for the immediate pick-up of the amodal information specifying change of distance. In the latter case it may have been that the infant has learned that the signal specifies an approach and hit.

2. <u>Social Interaction Games</u>: The nature of these games varied according to the age of the subject. Watson (1966, 1973) has argued for the importance of operant games to infants. He argues that the sorts of games adults play with their infants typically involve some sort of response-event contingency. It is the detection of such contingencies, he argues, which is the primary cause of smiling in these situations. Millar (1975) has argued that this is not the case and provides evidence that six-month olds exhibit more attention to non-contingent than to contingent stimulation. His study, however, used as a measure of attention a visual fixation preference paradigm using successive presentations. Lewis and Brooks (1974) have pointed out that such a measure of fixation preference is inadequate and that the amount of visual fixation may depend on several factors. One possibility is indeed that they do actually prefer to look at a non-contingent display, but it is equally plausible that they may look at it because it is

a violation of some expectancy - in this case, the non-contingent condition may be violating an expectancy they have of contingent stimulation and the infant is trying to determine what the violation is. Leslie (1979) has also reported the need for close monitoring of habituation effects in successive presentation measures of fixation preference. Papousek (1969) has in fact shown that the actual characteristics of the event the infant produces are irrelevant. Once the infant has detected the contingency between a given behaviour and a given event in the world, they lose interest. This would again contradict the hypothesis offered by Millar and would instead offer support to the type of analysis given by Watson.

One example of the type of social interaction game played in the following studies was a peek-a-boo variant. If we were to play a peek-a-boo game with the infant while he was wearing the guide, i.e. coming into the field of the guide and leaving it, we might expect the child to manifest smiling at this sort of game. This would show that the baby was noticing an object in the field of the guide and detecting the radial direction of the object. Bower (1977) has described the spontaneous exhibition of such behaviours in one infant guide user.

3. <u>Tracking</u>: Tracking of visually presented objects has been described by Bower (1974 b). Accurate sonically elicited tracking would indicate use of the radial direction index of the guide.

4. Reaching: Reaching in the sighted child has been shown to go through a well-defined progression, a progression that is not seen in blind children when reaching to noise-making objects. In this progression, behaviours such as hand-regard will have a different significance at different ages. Success of reaches, that is, whether they end in contact with the object, is one factor in the progression; whether one-handed or two-handed reaches predominate is another; anticipatory hand-shaping to the size of the object is yet another. A more detailed analysis of this progression as seen in sighted infants will be given in a later chapter (Chapter 4) as it bears directly upon the studies presented in Chapters 4 and 5. Here an analysis of reaching as it bears directly upon the blind will be considered.

The most detailed analysis of the development of reaching in the blind to audible objects is that offered by Fraiberg and her colleagues (Fraiberg, 1968, 1975, 1977; Fraiberg, Siegel and Gibson, 1966; Fraiberg, Smith and Adelson, 1969). These studies have shown that reaching to noise-making objects is usually delayed. When it does appear, it is not at all like the reaching of a sighted child of any age. Fraiberg (1968) describes the achievements of the blind child in reaching as "by no means equivalent to the demonstrations required in standard testing procedures for the sighted child".

Fraiberg's account of the development of auditory-manual co-ordination in one subject, Robbie, illustrates this well (Fraiberg, 1968, p. 279). Robbie closely parallelled the norms for a sighted infant in elevation of the head in prone position, rolling over, and sitting independently. From 9 to 11 months, however, despite a postural readiness for creeping, this was not achieved. Noise-making toys introduced would be attended to but not reached for until 11 months of age. Prior to this, he, like other blind infants, maintained his hands at rest at shoulder height but did not bring his hands together in the midline.

Fraiberg describes blind babies of 5 months of age showing:

> "no equivalent behaviours to 'reaching and attaining an object on sight'. There is no adaptive substitution of sound for vision at this age."
>
> (Fraiberg, 1968, p. 281)

Sounds are something to listen to; they do not indicate something that can be grasped. At 6 to 8 months the infant will search for an object if there is "immediately prior tactile experience of the object" (ibid., p. 282). Without this, there is no reaching to a noise-making object. Robbie first reached for a sound-making object at 11 months. The criterion for success was the demonstration of only <u>one</u> successful contact on sound cue alone in a one and a half hour session. This was in fact the optimum attained by many of the congenitally blind babies in her samples, many never even attained this level of auditory-manual co-ordination. Typically, the hands are held in the neonatal posture with no exploration of objects occurring even when placed in the hand.

The implications are clear. If we are to look at reaching behaviour while wearing the guide then we must look to see whether a reach approximates that of the sighted child rather than that of the blind child without a guide.

5. <u>Placing</u>: This class of behaviour was first described by Rademaker (1931) and further investigation of its presence was made by Walters and Walk (1974). The response consists of an extension of the arms while being held and brought towards a surface. There is some controversy over the origin of the response, with some authors saying that it is a purely visual response. Paine and Oppe (1966) have, on the other hand, argued that it is purely a vestibular or proprioceptive response as bandaging of the eyes does not affect it. However, in the latter case the fingers do not spread as the surface approaches; the fingers will only spread if visual information specifying approach to the surface is also available. Walters and Walk (1974) showed in their study that by controlling rate of approach, the vestibular component can be eliminated entirely. The purely visual nature of the response was demonstrated by the extension of the arms and spreading of the fingers. Bower (1977 d) has pointed out the necessity of correct handling, as incorrect handling of the infant may abolish the response. It is important in handling that the arms and legs are both left free. The full (non-vestibular) placing response appears in sighted infants at

around 9 months of age (Walters and Walk, 1974).

The response is of significance in comparative work with the guide for several reasons:

(1) it is visually elicited;

(2) it is recognised as demonstrating ability in spatial localisation (Walters and Walk, 1974);

(3) it has never been shown to occur in the blind population - infant or adult;

(4) it has never been observed in adult sonicguide users.

Indeed Kay and Strelow (1977) have discounted such a response as being impossible to obtain with the guide because of its engineering limitation (see Appendix II). In these studies we were therefore looking for sonically elicited placing.

6. <u>Object Concept</u>: These tasks, first described by Piaget (1936, 1937), show that the infant's understanding of objects goes through an invariant sequence of development. According to Wishart, "a belief in the permanence of objects is obviously fundamental to an understanding of objects and events" (Wishart, 1979). The development of the object concept may be classified into six stages (see Table 2.1). The six stages are identified by the infant's responses to objects which disappear from his visual field. With success at each stage, the infant is seen as having a more powerful concept of the object than in the previous stage.

Table 2.1 Summary of the characteristic failures and successes of the six object concept stages

Stage	Age in Months	Achievement	Failure
I	0-1	No particular behaviour when objects leave the visual field	
II	1-4½	Follows trajectory of object which leaves visual field	Continues to follow moving object when stops (movement error)
III	4½-8/9	Retrieves partially hidden object	Fails to retrieve completely hidden object
IV	8/9-12	Retrieves completely hidden object	Searches for hidden object in place where previously found - even if sees hidden in new location
V	12-18	Searches in new place if displacement visible	Unable to find object if invisibly displaced
VI	18-24	Can find object	

Traditionally infants' errors on standard object permanence tasks have been taken as evidence of their inability to represent an object which is out of sight; quite simply, out of sight is out of mind for the young infant. More recently, work by Bower (1974) and Wishart (1979) has suggested a different interpretation of the meaning of the responses obtained in these tasks. The problem, they believe, is one of understanding object identity rather than permanence. For the young infant, the identity of an object is very much defined in spatial terms. With development, the infant gains a growing comprehension of the spatial relations which are possible between objects without violating their identity. As a result he becomes more able to deal with search tasks which involve a spatial relationship between two objects, the occluder and the object itself.

Problems exist when attempts are made to present the equivalents of object concept tasks to blind infants and children. Fraiberg and her colleagues have spent many years in attempting to devise such tasks for the blind. At one time they felt they had succeeded in demonstrating Stage VI success with a blind child of 29 months. Later, however, they had doubt about this and it is now thought quite possible that, rather than an index of conceptual advance, this only showed learning in a specific task without the rigid criteria normally associated with success in these tasks with sighted infants. Even if this instance had been an accurate index of Stage VI acquisition the age of achievement would have been much later than with sighted infants. Piaget quotes a norm of 18 to 24 months for passing this stage. (Others have disagreed with this. For instance, Bower and Wishart (1972 a, b) provide evidence for success at 15 months for one group of intants. Escalona (1976) puts success in the range 9 to 25 months, with 17.2 months as the median.)

With the sonicguide we can provide echoic information as to the relative positions of objects. Signal change can indicate both movement of an object and when that object moves into a spatial relation with another object. It cannot, however, distinguish among all spatial relationships; it would, for instance, be impossible to tell from the signal whether an object had moved behind another object or inside it. This restriction aside, the guide would seem to allow for an auditory equivalent of object concept tasks to be presented to the blind infant.

7. Locomotipn: Attempts were made to elicit creeping, crawling or walking, depending on the age of the subject.

RESULTS

Two possibilities exist for presenting results of work with the sonicguide with blind infants. One is to present the results in summary tabulated form. The second is to present accurate observational reports. Both of these methods have associated problems.

With presentation of summary tables we incur problems which are akin to those experienced when we attempt to extrapolate from behavioural checklists (see Appendix I). They ignore, for instance, possible interrelationships of behaviours: for example, Fraiberg (1977) has shown the necessity for the pre-existence of auditory-manual co-ordination for the emergence of locomotion. Another problem is that this type of summary ignores any theoretical framework by which we may interpret developmental processes.

The presentation of results in descriptive observational form also presents a problem. This is that the implications to be drawn from the description, as it is in detailed form, may be difficult to extract. For these reasons, it was felt that both methods should be used. The results will be firstly presented in a detailed observational form and then brief tabulated summaries will be given from which comparisons may be later drawn. Subjects are identified by initials throughout for the sake of anonymity.

<u>Subject BG</u>: This subject's age at time of testing was 13 months. Blindness was due to bilateral anophthalmia. The parents of this child were very keen that she should do well in the testing and were willing that the testers attempt almost anything to establish some use of the guide. Both parents would also chastise the infant if she attempted to remove the guide. Auditory-manual co-ordination was already well-established, mostly one-handed with her right hand. Reaching was, however, in the stereotyped fashion of hands-to-midline (Fraiberg, 1968). She was able to walk while being held by one hand. She sat well and rolled over and sat up if she was laid on her back. This infant was well advanced compared to the average blind child, so much so that one of the testers reported that "she was more like a sighted child than a blind child".

On the first day, introduction to wearing the guide produced a mainly negative response, with a great deal of coaxing being required before she would wear it. While sitting on her mother's lap, she made parallax head movements while wearing the guide. When a soft toy was brought towards her, without touching her, she immediately started rocking to and fro, a behaviour which resulted in her bumping into the object.

On the second day she resumed rocking to objects in the midline. This was accompanied by laughing and gurgling. When walking, she walked towards doorways and aimed at a glass door which seemed to provide interesting signals. No anticipatory mouth opening was observed in a feeding routine. Her parents reported that in the evening she had spent a great deal of time reaching for objects which were within range of the guide.

On the third day, reaching and grasping were easily elicited. This was followed by her bringing the object to her ear (the sound then disappeared as the object was then out of the field of the guide). Sound, for this infant, seemed not to be a medium for locating objects, but to be a property of the objects themselves.

Subject SC: This subject visited the lab when he was 5 months of age. Blindness was due to agenesis of the optic tract. The parents of this child appeared well-adjusted to the child's blindness. They reported that they had not noticed any reaching to noise-making objects.

Observations without the guide consisted of the introduction of various noise-making objects. No head or eye tracking was observed to moving audible objects. No reaching was observed at all. During this time the infant retained his hands at the midline. Grasping was only elicited after an object had been placed in his palm, when the fingers closed around it.

On introduction of the guide, immediate stilling was observed. A soft toy was brought to and from his face in the midline without touching. After 15 presentations he reached to touch the toy. Grasping was not full, but only partial. Subsequent to this his attempts at reaching became more and more precise, with occasional grasping. When objects were presented off the midline he swiped at them. Although not accurate as to exact position, they were appropriate to sector and distance of presentation.

<u>Subject SI</u>: Age at testing was 13 months. Blindness was due to bilateral agenesis of the optic tract. This child's parents had also spent a great deal of time, effort and money to attempt sonicguide intervention with their child. They appeared well-adjusted to their child's blindness, and were positive in attempts to intervene with him.

Testing began without the infant wearing the guide. Reaching to a noise-making object was obtained after twenty to thirty presentations. A different audible object was then introduced. Reaching only occurred after the object touched his hand. A placing test to the floor was then tried. It was found that he stretched out his arms to the floor only when lowered rapidly. Only after he had touched= the floor did he open his palms out, indicating a purely vestibular response. When brought to a table edge, no placing response occurred. Stage III of the object concept was passed.

On first wearing the guide, no response was observed for the first two hours. After several presentations of an object in the midline he reached and grasped it, with the right hand going to the midline. He followed the movement of the object with his hand. On the re-introduction of an object in the midline he began rocking back and forth. The first time he did so he bumped into the object dangled in front of him; subsequently, he varied the rocking so that he gently tapped the object with his head. After repeating this 20 times, he sat back and reached out to take the object. He spent a great deal of time in "hand regard" (Bower, 1979 a), seemingly finding the echoes generated by his hand to be interesting. As objects left the field of the guide to either side he would track them by head movements.

On the second day of testing, reaching and grasping with the guide advanced rapidly. Anticipatory grasping was noticed as objects were brought to his face; as the object was withdrawn the hands followed after it. When the object was outwith reaching distance the hands were withdrawn. Radially directed reaching was again accurate only to the sector of the object's position.

Subject SN: Age at first testing was 8 months. The cause of blindness was twofold: bilateral micropsia and retrolental fibroplasia. One eye was completely destroyed. The central area of the other was detached. Ophthalmological reports indicated that only light perception would be possible from that eye. The infant was small for his age, reflecting his unknown degree of prematurity. Despite this he could sit well independently, and appeared to have a few well-established games to play with his mother. The attitude of this child's parents will be discussed in the next chapter as this infant was one of those who participated in the longitudinal study. Sporadic reaching (one-handed) was observed to audible objects. Attempts to elicit crawling or creeping were unsuccessful.

When the guide was placed on his head he did not resist it at all. At first he showed no reaction to objects presented in the field of the guide. His initial response was to scan the test room. At this time he was totally silent. He would not engage his mother in their usual games. This phase lasted for 20 minutes. The baby was then settled in a baby chair at a table, where he continued his scanning. A soft toy was brought to and from his face ten times without touching. The infant's response was to turn and shake his head, as if to rid himself of the stimulus. On the eleventh approach, the infant was gently tapped on the face with the toy. This produced instantaneous stilling. There was no discernible reaction to the next approach and tap. The next produced a broad smile. After several repetitions, the baby seized the object and threw it away. Subsequent presentations (nine) in three different positions elicited the same behaviour, with the toyubeing seized and thrown away. In an attempt to begin object permanence testing, a toy was brought into the field of the guide and placed on the table top. The infant tracked it down to the table-top and in so doing discovered the edge of the table. He scanned vertically up and down for some minutes, with some accompanying vocalisation. He then reached very slowly to the table edge. The presence of his hand in the field produced some startle. The hand was moved slightly in the field for some minutes. After this, the infant began to cry so vigorously that testing was terminated.

After lunch and a brief nap, testing was resumed in the same way, with the baby seated at the table. There was again a great deal of scanning, with prolonged attention to the table edge and hand. Only one hand, the right, was ever inspected. After some time a familiar chew toy was introduced to the field. The baby threw it away. On the second presentation, he was prevented from doing that and the toy was inserted in his mouth. He chewed happily. It was taken away and the sequence repeated five times without the toy being thrown away. After this the baby reached to take the toy, with two hands, and placed it in his mouth. On the next trial the toy was presented in the field and then brought down on to the table before it could be grasped. The baby reached out to take it from the table. The reach was a bimanual sweep (Bruner, 1968). This was repeated twice. On the next presentation a metal box was placed over the toy before grasping could take place. The baby stopped his reach and focussed on the table edge. After this, attempts at social play were begun. These were not successful.

Subject LF: Age at the time of her visit to the lab. was 20 months. The cause of blindness was given as Leber's congenital amaurosis. Ophthalmological evidence indicated no E.R.G. and no V.E.P. General physical condition was very good. The parents of this child were extremely protective, and asked that no one speak in front of her as she was disturbed by stranger's voices. They found it difficult to accept that they had a blind infant, and treated the session very much as if an "instant cure" had been found for their daughter's blindness. They particularly resented anything which appeared in any way "over-experimental".

Before wearing the guide the infant reached to an audible object several times. Reaching was bimanual to the midline. She walked with one hand held, although in a clumsy goose-stepping manner.

When the guide was introduced she did not attempt to remove it. However, her reaction to it was negative in other ways. When it was first put on, she sank from a standing position to a sitting position, and would not get up again. Presentation of objects, attempts to engage her in social games, etc. resulted in terrified screams. Virtually every technique for quieting babies that was known to the assembled group was tried, without success. After one and a half hours the session was terminated.

Subject MP: This subject and the next subject are a pair of male twins aged 18 months. The cause of blindness in both was given as Leber's congenital amaurosis. There was no recorded V.E.P. from either child. General physical condition was good. The parents of these two children were both eager to attempt any possibility in intervention. They were realistic as to the difficulties they would experience in the future in bringing up two blind children. The parents had first contacted the hospital at 3 to 4 months of age when they had thought that something was wrong with the children's sight. They had initially been told that there was nothing wrong, but, on a subsequent visit, they were then told that both children were totally blind.

Presentation of audible objects to MP produced reaching and grasping. If the initial reaches were inaccurate, he would search further. He could walk with one hand held and would walk while holding onto furniture.

His initial reaction to the guide was negative, in that he tore it off. Presentation of sweets distracted him long enough that this response waned. However, subsequent testing with the guide indicated that its effect on performance was, if any, negative. No reaching was seen, even when noise-making toys, which had previously been successful in eliciting reaching, were presented. Walking would be more accurately described as dragging, and was accompanied by vocal protest. After one hour the parents decided that further testing was a waste of time.

<u>Subject JT</u>: Testing occurred in the lab. on the same day as his twin brother, at age 18 months. As previously stated, the diagnosis was again Leber's congenital amaurosis. This child, although ophthalmologically blind - no V.E.P. - could clearly see to some limited extent, in that he would reach out and take white objects against a dark background. The smallest object so taken was a 2.5 cm. cube. We were not able to determine the minimum necessary contrast ratio. Reaching to audible objects was also established. The reaching pattern in both cases was a one-handed straight-line reach, with groping at the end. Walking, with hand held, was also possible. The guide initially produced no negative response. Indeed reaching with the guide became more and more precise (8/10 successful reaches with the guide as against 4/10 without). Attempts at inducing locomotion while wearing the guide, however, provoked distress. Further attempts at social interaction games

produced progressive distress and eventual immobility. After a rest period, testing was tried again with the same results. The rest of the visit was spent on exploring the possibilities of the infant's residual vision. (These latter two subjects were studied on a long-term basis by Dr. I. Neilson. The results of this work are relevant to the problems involved in defining "blindness" - a problem which has already been referred to. The results obtained are discussed in Appendix III.)

Subject AN: Age at testing was 6 months. Cause of blindness was bilateral anophtholmia. As this child also participated in the long-term study, discussion of parental attitudes will be left until the next chapter. Neither peek-a-boo nor game playing elicited any sonicguide-specific response. Standard object permanence testing was impossible since the infant would not sit at a table nor reach for objects on a surface. Objects were presented for tracking tasks. The infant would track an object through 120°, if the object was out of reach. Otherwise swiping occurred. When the object stopped in its trajectory, the baby also stopped. When the object changed direction, the infant's head changed direction correspondingly. A screen occluding the centre 30° of the track was inserted. The infant tracked the object to the edge of the screen but made no attempt to track through the screen. This presentation was repeated six times, with the same response. When laid on her back with slight propping, reaching to various toys was observed. This was accompanied by smiling and laughing. After this, extreme boredom set in and some swiping games were begun. Because of the age of this subject, placing and locomotion tests were clearly inappropriate.

Subject MT: This child was 25 months when visited in his own home. Cause of blindness was retrolental fibroplasia. Retrolental fibroplasia was due to incorrect oxygen supply during incubation - MT was born three months premature. While in incubation, which lasted for five months, tubes inserted in his throat had damaged his vocal chords. It is not yet known whether this damage will be permanent. Despite MT's age he had not yet made any attempts at speech. During the test session no sounds whatsoever were heard to come from him. The testing session lasted approximately two hours. The mother was present throughout the whole session; the maternal grandparents were also present for the second hour. The mother appeared well-adjusted to MT's condition, although somewhat bitter with the hospital at which he had been born. This was due both to the fact that the blindness stemmed directly from the period of incubation and to the fact that they found it difficult to obtain information from the hospital; they had not, for instance, been told until very late about the possibility of speech impairment. The mother was also concerned at the lack of facilities available to her as they lived on an outlying housing estate which entailed a large amount of travelling to nursery. She clearly spent a great deal of time in encouraging MT to explore his home environment. The mother was pregnant again at the time of testing and looking forward to the birth.

When the testers arrived, MT was walking around the kitchen. This he did by sideways steps while holding on to the available furniture. When he came to a new piece of furniture, he would slap it with his open hand. This slapping was only done after initial contact with the item. The impression was gained that he was still familiarising himself with the room and its contents. The tester picked up MT and took him to the centre of the room. He then asked him to find the sink. No orientation of head occurred, and it appeared at first as if he had not heard or understood the request. He then struggled to be put on the floor and when he was put down, went to the sink and touched it, after first touching the refrigerator. A series of unusual head movements were made, however, before he went over to the refrigerator. These consisted of tilting the head to the left and then to the right shoulder. It appeared that he used the sound of the refrigerator and of the freezer to determine the positions of other objects in the room.

Testing then moved to the sitting room and attempts were made to establish if any measure of vision was present. These consisted of a series of soundless objects being brought to and from him and tracking of soundless objects.

All attempts resulted in no apparent visual capacity. Various familiar noise-making objects were then introduced at a number of positions. All resulted in accurate reaching and grasping to the location of the objects. Anticipatory hand shaping was accurate for some toys. The sound of one toy elicited a very negative reaction, producing extreme distress. Again, locomotion around this room was accurate with MT being willing on occasion to venture into the middle of the floor with no means of support. On these occasions he walked forward but with hands-to-midline, a common 'blindism'. On these occasions a blindism of the left hand being shaken up and down was also noticed. This was only seen when walking.

Initial attempts to put the guide on were unsuccessful with him pulling it off instantly. A thin hat was therefore used and the guide worn over the hat. The subject was sitting on the floor when the guide was first switched on. This produced instant stilling; he then slowly turned his head to the right, while pointing to the floor. A wooden drum was introduced into the field. He leaned his head forward and tapped his forehead on the drum. This drum was moved to different distances in the midline; each time he approached and tapped his forehead on the drum in this way. On the fourth presentation he turned his ear to the drum. This resulted in the object being lost from the field of the guide. This produced immediate smiling, without the object touching the guide. The object was then moved to the left and he tracked its movement through

45°. The object was then lowered to the floor. Again he followed its trajectory, this time by a head movement from midline tilting to the shoulder. He then stood up and walked two paces, the object was held in front of him and then lowered. He again tilted his head to the shoulder while bending down and following the object's descent. This again elicited broad smiling. He then walked over to a chair and slapped it. It was impossible to tell whether the guide was used for this or not.

MT was taken over to a television set which the mother said he often played with. After a few seconds he began to rock back and forth, stopping before touching the television. He then made lateral head movements, fixated on the right hand edge of the television and then slapped its side. Attempts to interest him in his own hand by introducing it into the field were unsuccessful. Next, MT was put on his rocking horse and, while he rocked, objects were brought into the field. After hitting an object twice, he was able to accurately decelerate before hitting objects introduced at different distances. A noise-making object was then introduced for which he reached, no previous reaching having been elicited with the guide alone. He discovered that the two sounds (from the guide and from the rattle) were independent and explored the edge of the object with the guide. He then took the object to his ear three times, meanwhile not shaking it. He was apparently listening to the sound from the guide. The object at his ear was, of course, out of the field of the guide.

Subject XL: This subject was 8 months of age when visited in his own home. XL was the younger of two blind children (brother of MK 6 see below). It had at first been thought that his brother's blindness was due to retrolental fibroplasia and then to Norrie's syndrome. The birth of XL had, however, suggested a hereditary cause. This cause has not, as yet, been diagnosed. This is causing a great deal of concern to the parents, as the father has six brothers, one of whom is about to have a child. The father has recently become unemployed.

With sighted children, most parents continually compare the development of their children when they have more than one infant. With parents who have more than one handicapped child - particularly when the same handicap is present - this continual comparison is more evident. The parents of these two blind children were no exception. Obviously, it must seem even more necessary to monitor development and check if things are going wrong with handicapped than with normal, sighted children. Unfortunately, such comparisons have drawbacks. One is that incidents remembered of one child may not be accurate as to their timing or even as to their occurrence. For instance, when did the two infants first start reaching? A second drawback is that of a possible "halo effect", where one factor remembered may disproportionately affect the recall of other events. A third drawback which is related to the latter is what the effects are on the parents of them making these comparisons, especially, as in this case, when the comparisons are, for the younger infant, negative. What do the parents do after having made these comparisons? With no outside assistance it is all too easy to accept that 'one will never be as good as the other' and act accordingly. This may result in a downward spiral of 'lack of abilities' leading to lack of stimulation of the infant which in turn, jeopardise the chances of these abilities ever emerging.

Testing without the guide was conducted with XL lying on his back. Approaching and receding soundless objects were presented. No blinking or other defensive responses were observed. No pupillary responses were observed to a bright light. The father reported that he had occasionally seen the baby startle when he had used a camera flash close up. He did not think this was due to the shutter sound. The possibility of light perception therefore remained, although in the two hours of testing no behavioural evidence of vision was observed by the testers.

Familiar sound-making toys were presented to the infant. These were brought to and from his face while emitting sounds. No evidence of defensive responses, such as interposition of the hands between object and face occurred. When presented off the midline, no head orientation to objects was observed. No reaching or grasping was observed for the first twenty minutes of presentations. Grasping and tactual exploration was observed only when objects were laid on his chest. No difference in this behaviour was seen for soundless versus noise-making objects. The parents also reported that they had never seen any sign of auditory-manual co-ordination at any age. After twenty minutes, a sound-making object was brought to the back of his hand. This resulted in him grasping the object. Thereafter five reaches were observed to sound-making objects at several locations. Two were successful in contact, the others were to the correct sector. One of the two successful contacts ended in tactual exploration. No attempts were made to observe crawling or standing as the infant would not sit unaided. Smiling was observed when one of the testers tapped a soft toy on his nose. Smiling only occurred after tapping on the nose and no attempts to reach for the object occurred.

The sonicguide was introduced while XL was sitting on his mother's knee, facing into the room. Immediately the guide was switched on, he began to make lateral head movements through 120°. This brought one of the testers into the field in the right hand sector. At this point broad smiling was observed. A small soft toy (10 cm. x 5 cm.) was then brought towards his face, without touching it. This immediately produced broad smiling. On the second presentation, he reached out to the object. The reach was to the appropriate sector but not accurate within the sector, and distance was inaccurate. He then turned his head to the side and lost the object from the field. Rapid lateral head movements were then initiated until the approaching object was recentralised. This was repeated with each of the next three presentations of the object.

On the fourth presentation he reached and grasped the object with his right hand before it had started its approach; the object was then taken to his mouth. A further presentation produced a direct reach to the object. His own hand was then introduced to the field and he spent one minute waving his hand into and out of the field of the guide, finally holding it in the field for several seconds. Attempts at eliciting radially directed tracking were unsuccessful. Assessment of object concept was also impossible due to the great difficulty experienced in getting the infant to reach. At this point testing was terminated as the elder brother was beginning to resent the attention being given to XL; he started making a great deal of noise, thereby interfering with the signal from the guide.

Testing was resumed half-an-hour later with the infant lying on his back. He was supported by a pillow at his head, thereby leaving his arms and legs unrestricted. The mother began peek-a-boo games with the infant, games which ended in touching his nose. The third time she entered the field, a broad smile was obtained from the infant. As the mother left the field, he followed her by rotating his head thereby keeping her in the field of the guide. The mother then remained soundlessly in the field but at the limit of his reaching length. He reached up with his right hand and grasped her chin. Several more attempts were made to elicit reaching with the original soft toy. None of these were successful, with the hands being held in the midline. The infant then became irritable and testing was terminated.

Subject MK: This subject, although older than the others, is discussed here as he is the brother of the previous subject and was seen at the same time. He will, however, be classed with the school-age children reported next, as this child was $4\frac{1}{2}$ years when tested. As previously stated, the cause of blindness has not as yet been established. He had been attending a nursery for several months and was attending five full days per week. The nursery was for normal, sighted children and it had taken a great deal of effort by the parents for him to be placed there. He is the first blind child to be placed in a nursery for sighted children in the area. At first, the reaction by the staff had been negative but now all but one of the staff are enthusiastic about him being there. The parents reported that he gets on very well with the other children and that they accept him very well, merely stating that "MK's eyes do not work properly" and compensating for this readily.

Testing of MK was difficult. Having just returned from a full day at the nursery, he was very tired and, in addition, somewhat suspicious of the motives of the testers. It was felt, therefore, that the time available should be spent on working with the guide. No attempts at ascertaining whether any residual vision was present were made. It is therefore possible that some degree of functional vision may have been present. MK walked well independently and could find his way around the house with no apparent difficulty. His speech comprehension and production appeared normal with one exception. He never used the first person pronoun 'I'. He always used his own name in place of the first person pronoun, and previously, the parents reported, had used the pronoun 'you'.

Introduction to wearing the guide was established only after a series of bribes. A small soft toy was initially brought to and from his face, without touching it. His left hand went up to cover his ear. He then removed his hand and replaced it, repeating this action several times. It appeared that he was attempting to cut off the incoming change of sounds. Larger objects were then introduced into the field. These were allowed to touch his face. No response was observed. Only after his mother had exhorted him to "catch the ball", was there any evidence of reaching. The reaching was done by putting his palm out to touch the ball which was then tactually explored. Three subsequent reaches were observed. Anticipatory hand shaping was only observed in the instances when the mother gave him the above cue. On presentation of the ball from a new trajectory, one accurately directed reach and grasp was observed while the object was moving.

Table 2.2 presents the results obtained with the cross-sectional infant sample in summary form (MK excluded).

TABLE 2.2 Summary of results obtained with infants in short-term study

Subject	Age (mths)	Reaching		Responses			Object Permanence *	Locomotion			Other Comments
		Midline	Radial	To approaching object	Tracking	Placing		Crawl	Creep	Walk	
SC	5	After 15 trials. Accurate reaching to position.	No accurate reaching but swiping to correct sector.	Hand interposition between face and object.	Not obtained	Not appropriate					
AN	6	After 10 trials. Accurate for position.	Immediate transfer to new position.	As above	Through 120° if object out of reach and not on table top.	Not appropriate					Toy presentation elicited laughter
SN	8	After 20 trials. Accurate for position.	Immediate transfer to new position.	As above	Tracked object to table surface and stopped.	Not appropriate					
XL	8	After 2 presentations. Accurate for	None	Hand interposition.	Only of mother.						Social games with mother. Hand regard.

Table 2·2 (contd.)

BG	13	After 25 trials. Accurate for position	Transfer not immediate.	As above	No tracking	Not obtained				Towards doorways and glass doors.	Object brought to ear.
SI	13	After 25 trials. (Only if within reach)	Swiping to correct	As above	No tracking	Not obtained					Rocking to and from object. Hand regard.
LF	18										No responses with guide in 1½ hours of attempts.
JT	18				No tracking but tracking to a visual object.					Without guide.	Residual vision explored.
MP	20										Distressed by experimental situation.
MT	25	None	None	None	Radial tracking.					Without guide.	Object brought to ear.

* Insufficient time to test this aspect of behaviour in short-term subjects.

<u>BLIND SCHOOL-AGE SAMPLE</u>:

All subjects in this sample attended the local blind school. Ages ranged from 5 to 11 years. Seven totally blind subjects were seen. Of them five were congenitally totally blind. The two others had been partially sighted at birth but later became totally blind. Subjects were selected by the occupational therapist attached to the school and represented varying abilities in mobility and locomotion.

The tasks presented to them consisted of:

(a) a search task with the guide for a single object (a large Varooshka doll). (Due to lack of time available, auditory-manual co-ordination was not investigated.)

(b) a manipulation/stacking task carried out with, and without, the guide (<u>MK</u> excluded).

(c) observations of locomotion with and without the guide.

<u>Subject BM</u>: Age at testing was 6 years 6 months. <u>BM</u> had been totally blind since 3 years of age due to a viral infection. Previously he had been partially sighted. He was very lively, reported to be the most adventurous in his class. His speech appeared normal and he continuously asked questions during the test and requested more information. When the guide was introduced and switched on, no head movements occurred. He was then asked by the tester,

'What is happening?' He replied that the sound was going up and down.

(a) Search task: An object was brought to and from the guide in the midline without touching him. No reaching or searching with his hands or with head movements was seen. After several of these presentations, the object was moved laterally right and left. No corresponding head movements were observed. The object was then brought to touch the guide. Immediately he reached up with both hands to grasp it. Reaching and grasping only occurred thereafter when the object touched him. After this had been observed three times, he took the object to his right ear and 'listened' to it. The object was then, of course, out of the field of the guide. The power pack of the guide was then placed in his hand. He was fascinated for several minutes in playing with the volume control. He then brought the power pack to his ear and shook it several times, then transferred it to his other ear. Thereafter he was informed that the change in signal signified that the doll was approaching to, and receding from him. This resulted in his holding his hands to midline and sweeping laterally with both hands.

(b) Manipulation/Stacking task: This task consisted of placing a small doll inside both halves of a larger doll and placing the halves together. (The large doll was the object used in Task (a).) This took 50 seconds without the guide and 65 seconds with the guide.

(c) Locomotion: When asked to use the guide to tell him when he was coming to objects BM appeared totally confused and bumped into many obstacles. Without the guide, he was able to find his way around the room relatively easily. The guide seemed only to introduce a confusing factor. That this was not due to a fatigue effect was borne out by the fact that, despite bumping into objects, he still found the signals interesting.

Subject BY: This subject was again male, 5½ years of age, and had been blind since the age of 3 years 9 months. Previously he had been partially sighted. Blindness was caused by raised oxygen pressure in the eyes. BY was one of the more timid boys in his class and found difficulty in independent walking. The orientation and mobility specialist had begun to work with him. Although at first a little reticent about the testing, he was encouraged by the enthusiastic comments of BM and was eager to participate. Initial introduction of the guide produced an immediate stilling and then his right hand was brought to his ear. He then turned his head from right to left and back to the midline. When asked, 'What is happening?' there was no reply.

(a) Search task: The doll was then brought to and from his face, again without it touching him. No response was observed, nor was there any radially directed tracking to moving objects. The object was then tapped on his nose, and he reached up to touch it, asking why it was making that noise. After two more approaches ending in contact, he took the doll to his left ear and shook it. Again this meant the doll was lost from the field of the guide. No accurate reaches were observed until he was told that the signal change correlated with the object changing in distance. This again induced sweeping of the hands from left to right until contact was made, then the object was grasped. No radially directed reaching or tracking was observed.

(b) Manipulation/Stacking: Results for the same stacking task as before were: 95 seconds with the guide and 80 seconds without the guide.

(c) Locomotion: As previously stated, independent locomotion without the guide was difficult for him. His locomotion with the guide showed no improvement, and, like BM, he appeared to find the signals confusing.

Subject BL: This subject was again male, 8½ years old. Blindness was due to congenital microphthalmia and congenital cataract. BL was selected by the therapist as he was the most mobile of the children in his class. He was also the most intelligent according to his teacher. On the route from his classroom to the testing area, he was able to find his way entirely unaided. This route included a 50 yard walk across a large grassy area which was negotiated without difficulty. He was very enthusiastic about wearing the guide and has already been told that the signals were going to tell him about objects surrounding him.

(a) Search task: When he was introduced to the guide, he was again asked the question, 'What is happening?' As the doll approached in the midline, he answered, 'The sound is going down'. This was repeated several times and he was then asked, 'What is the noise telling you?' He replied, 'I don't know what to do'. The object was then tapped on his nose and he reached and grasped it. He then held the object and tactually explored it, finally bringing it to his right ear, where the object was again out of the field of the guide. He then held the object in various positions, as well as moving it laterally. The doll was then reached for directly and grasped accurately (two handed) as it was brought across the field to the midline. This occurred twice. On both occasions the object's movement was not followed by head movements; BL waited until the sound was equivalent to what he had associated with the object in the midline before reaching. Two accurate radially directed reaches to off-midline positions were obtained after he was allowed to follow the object with his hand. Subsequent approaches of the object produced the statement, 'Here it comes'.

(b) Manipulation/Stacking: In the stacking and manipulation task he appeared in both cases to be using tactile information. This is confirmed by the results obtained of 8 seconds without the guide and 9 seconds with the guide. Also tested in this subject was the ability to discriminate sizes with the guide. One object was four times the size of the other. Both objects were presented at the same distance and 15 cm. apart. With the guide only, he could not pick out the smaller object. Only with manual exploration was he able to discriminate the sizes of the objects.

(c) Locomotion: BL then asked if he could walk around with the guide. He used the guide to detect obstacles in his path and to change direction to avoid them. No head movements were observed during this phase. To counteract the possibility that he was using his already acquired knowledge of the layout of the room (with which he was familiar), the testers would soundlessly move into his path. In all cases, he avoided walking into them. He made no distinction between a small boy standing in front of him and any of the adult testers standing in his path. Later he requested that he be allowed to use the guide to find his way back to the classroom. It was not possible to say whether he was using the guide to follow the route or was finding his way in the same manner as he had followed to arrive at the test area.

Subject BS: This child was again a congenitally totally blind male. His age was 8½ years. Cause of blindness was tapeto-retinal degeneration. BS was, according to the therapist, an average child in the class and found problems in orientation over a long route. On the way to the test area he frequently had to be told which way to go, the open grassy area proving particularly difficult; only when he walked into a flower bed did he realise that he had gone in the wrong direction.

(a) Search task: He was at first reticent to wear the guide but was encouraged by BL to try it. During the first few approaches in the midline, he held onto the left side earpiece. Only when the object was tapped on his nose did he touch it with his hand, this being followed by taking the object out of the field of the guide and exploring it tactually. The object was then brought into the midline, at which point he raised his hand to each ear in turn. Subsequent approaches only elicited grasping when the object touched his hands, with the hands being held in the midline position at his chest during this phase. Radial movement of the object elicited no reaching or tracking. BS then asked if he could hold the power pack and work the volume control. Immediately he was given it, he held it up to his left ear.

(b) Manipulation/Stacking: This task took 17 seconds with the guide, 9 seconds without the guide.

(c) Locomotion: When he was walking with the guide he held the power pack to his ear throughout. Only when he had bumped into the obstacle would he turn away from it. His locomotion only improved when BL insisted on walking behind him, listening to the signal and telling him when obstacles were in his path.

Subject BA: Age at testing was 9 years 9 months. Blindness was due to bilateral micropsia. This child was described by her teacher as average in intelligence although poor in orientation tasks.

(a) Search task: When first tested with the guide, she produced a response to the 'What is happening?' question of, 'The sound is getting lower and higher'. She then said that something was going away and coming back from right to left. (It was later found out that this child and the next had been primed as to what to expect in the testing session.) No reaches were observed to objects even after the subject had been touched by them. She constantly attempted to catch the object by throwing her arms backwards, stating that the object was behind her. Size discrimination was achieved successfully only after she had touched the object with her hands.

(b) Manipulation/Stacking: This task took 9 seconds with the guide, 10 seconds without the guide.

(c) Locomotion: Objects were first touched and then manually explored before avoidance. Her teacher reported that she appeared to be slightly improved on mobility with the guide. Any improvement, however, was very gross in nature. No discrimination was observed between different obstacles and she appeared to be able to use the guide purely for detecting large obstacles. Walls were only much later discovered as being in her path.

Subject BK: Age at testing was 9 years 6 months. This child could see to some limited extent, in that she knew when there were changes in light and could distinguish large differences in the shape of objects or people. The therapist reported that she was the most intelligent in her class (with an I.Q. of 148) and also the most mobile.

(a) Search task: On first wearing the guide, objects were brought to and from her in the midline, without touching. She reported that the sound was getting lower. She introduced her own hand to the field of the guide, then explored her hand and other parts of her body by head movements. She was then asked to find the object. She reached out with both hands, palm out in the midline; grasping was tactually elicited. She took the object and presented it in various positions in the field of the guide, comparing it with the signal from her hand and from another object. She appeared to be doing this in the same way as BL, i.e. by response matching. No tracking was observed, nor was there any sign of size discrimination. She was unable to tell whether there was more than one object in the field of the guide. At this point, she commented that wearing the guide was 'just like being able to see'. When asked to be more specific, she replied that she could tell how near and far things were. (It was later found that this analogy was presented to her by her teacher the previous day in preparation for our visit.)

(b) Manipulation/Stacking: This task took 13 seconds without the guide, 18 with the guide.

(c) Locomotion: BK already had a good knowledge of the testing room and was able to walk around without bumping into obstacles. Her teacher later reported that she was able to avoid large obstacles unaided. It is possible therefore that she has more vision than the light perception reported. She quickly picked up the meaning of the distance signal of the guide and was able to avoid obstacles, although she showed no distinction between responses to objects of different textures, relying on touch to provide her with this information.

Table 2.3 presents in summary from the results of the search task and locomotion with the older blind subjects.

Table 2.4 presents the results of the manipulation/stacking task with these children.

DISCUSSION:

It cannot be denied that the data described above are a great deal less clear-cut and a great deal more variable than would be desired. That is an unfortunate aspect of research with this kind of population and of work with handicapped infants in particular. (The problems of researching with blind infants are discussed more fully in Appendix I.) Aside from that, there are problems in interpretation of the results. If we look briefly at

Table 2.3 Summary of results of search and locomotion tasks with older blind subjects

Subject	Age	Search task wearing guide					Locomotion	
		Reaching				Tracking	Without guide	With guide
		Midline		Radial				
		Before contact	After contact	Before contact	After contact			
MK	4yr 6m	None	4 - tactile exploration	None	1 reach/grasp (tactile)	None	Good mobility	Not observed
BY	5yr 6m	None	Sweeping of hands until contact	None	None	None	Poor mobility	No improvement
BM	6yr 6m	None	Always after contact	None	None	None	Average mobility	Confused by guide
BL	8yr 6m	None	Response matching of signal at midline	None	After following with hand	None	Excellent mobility	Obstacle detection
BS	8yr 6m	None	Only after touching hands	None	None	None	Poor mobility	No improvement
BK	9yr 6m	None	Response matching	None	None	None	Excellent mobility	Obstacle detection
BA	9yr 9m	None	None	None	None	None	Poor mobility	Little improvement

Table 2.4 Results of Manipulation/Stacking Task, both with and without Sonicguide. Order of presentation was randomised. (Subject MK excluded.)

Subject	Age	TIME TO COMPLETE TASK (secs.) Without Guide	With Guide	D score
BY	5yr 6m	80	95	+15
BM	6yr 6m	50	65	+15
BL	8yr 6m	8	9	+ 1
BS	8yr 6m	9	17	+ 8
BK	9yr 6m	13	18	+ 5
BA	9yr 9m	9	10	+ 1

Tables 2.2 and 2.3, which compare sonicguide use in infants and older children, we see that some of the children in the older group were able to perform certain tasks with the guide. Does this mean that they were able to use the guide? The question then arises as to how we define what we mean by "use".

As was previously stated (Chapter 1), the sonicguide provides a large and complex amount of information - as to distance, size, direction, texture and so on. What behaviour changes would indicate that any of this information is being used? To answer this it is necessary to draw a distinction between the responses observed which indicate that the specific information provided by the sonicguide is being used, as opposed to the information which is also characteristic of noise-making objects, information to which all subjects will already have necessarily been exposed. An example may highlight this distinction. Suppose we present a silent object in the field of the guide. The immediate consequence will be a change in the signal at the ears. That signal will have the same characteristics as would be produced by introduction of a noise-making object in a slightly different place (see Chapter 1). It will, however, have many other characteristics in addition to these, characteristics which are guide-specific. The problem then arises when we attempt to differentiate out responses that would indicate use of these other characteristics. There are several methods available to us to do this. One is an empirical method. In this we would compare response to noise-making objects (without the guide) with response to silent objects in the field of the guide. An example of this can be seen if we look at the reaching response of BG (13 months) in Fig. 2.1. Here we have compared the pattern over time of a reach, ending in contact, to a silent object in the field of the guide, with that of a reach, ending in contact, to an audible object. To do this, a plot was made of the index finger at the beginning of the reach, at contact with the object, and at every ten frames of a video-tape recording (i.e. at 0.2 second intervals).

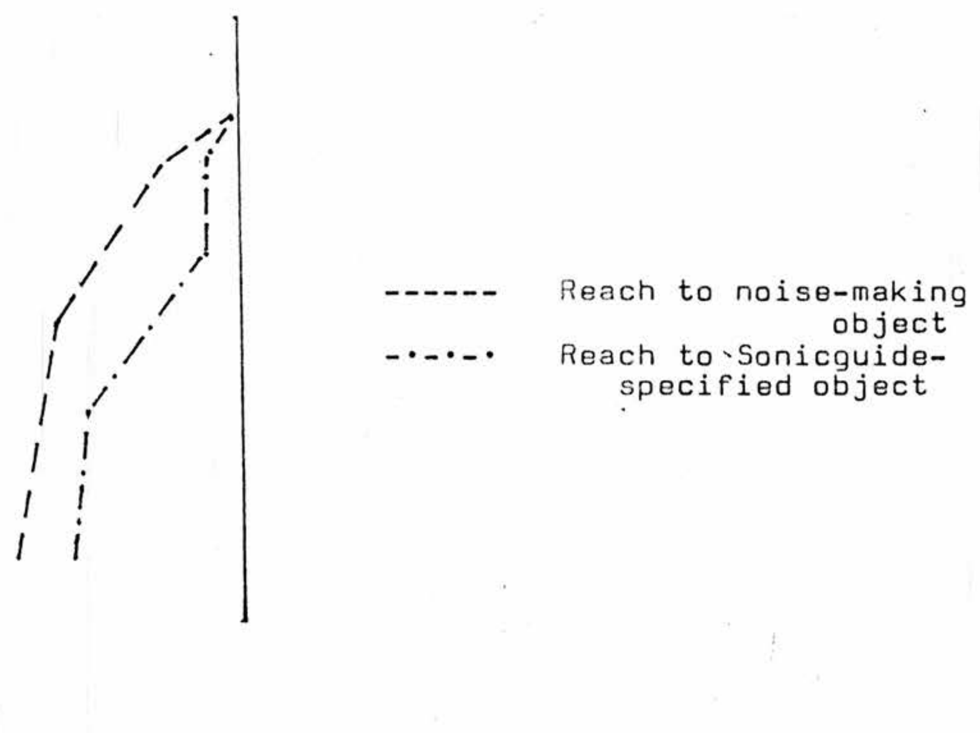


Fig. 2.1. Reaching patterns of Subject BG.

Fig. 2.1: Reaching pattern of Subject BG

From the graph we see that very little difference in reaching patterns exists for the two conditions. BG appears to be using the information provided by the guide in the same way as the sound produced by noise-making objects.

A less directly empirical method would be to list the responses that demand the pick-up by the infant of guide-specific qualities of the auditory signal. An example of this can be seen if we compare the extraction of the distance dimension by the subjects. In the case of the older children in the sample we see that few could use this quality of the guide at all. Certainly, none could answer the question posed to them, "What is happening?" with other than a modality-specific statement such as, "The sound is getting lower". Two children, however, BL and BK, the best of this group, were able to extract the dimension of distance rapidly. Crucially, though, they did this by quickly learning that a certain low sound indicated they were approaching an obstacle, and using it as a means of detecting an obstacle in the midline. Similarly it was only after the object had tapped them on the face that they were then able to use tactile exploration to confirm the presence of the object. They did not spontaneously use the amodal properties of the signal to reach out. In contrast, with the infant group, we see that the younger infants were able to extract the distance dimension rapidly and to make accurate reaching responses in depth, without prior tactile information.

A less obvious method for comparing responses which are guide-specific with those which could be elicited by noise-making objects is to utilise the control aspects of the guide. The Sonicguide provides the wearer with a degree of control over the auditory information which is coming to the ears, control which is not available with the auditory information emanating from passive sound-making objects. We can again see evidence of differences between our groups in ability to make use of this potential for control. With many of the young infants, we see a spontaneous use of either rocking (which, although a common blindism in older children, was not seen in these infants when not using the guide), indicating pick-up of the distance dimension, or of parallax head movements, providing radial direction information. Subject SI (13 months) provides a good example of the use of such rocking, rapidly calibrating his movements so as to stop just short of the object. With the school-age sample, none of the subjects evidenced this. Interestingly, MT, a 25-month old, only picked up this information after sitting on a rocking horse whose movements accentuated the signal changes of the guide and bumping into an object. This produced stilling and subsequently he was able to use this information to decelerate before hitting objects in his path. This subject could also track objects although he made no spontaneous head scanning movements. No reaching was, however, seen with this subject. This subject appeared to be making head movements purely for the interesting sounds made. That the only times he reached were to audible objects bears this out, as does the incident of his taking an object to his ear.

Neither did any of the school age sample show any use of parallax head movements. With BL and BK (aged 8½ and 9½), who were the best in this group, we see evidence of the matching strategy mentioned above. They never tracked objects nor made spontaneous head movements to scan for other objects. Instead, they only reached when the object was in the midline. These subjects were apparently matching one certain signal with one particular position. New objects were not adjusted to, for size, for example, but tactually explored for such additional information.

From the above examples we can see that there are differences between the older and younger group in their ability to use the information supplied by the guide. It would appear that the younger the subject the more rapidly can use be established. Age appropriate use was seen within minutes for the younger infants and within a few hours for the older infants. Bower's (1979 c) suggestion of a six-month of age cut-off was not supported. While taking a little longer to show use, neither edges nor doorways presented any problems to any of the older infants. Indeed, for two of the infants these were almost the first external properties to be discovered. One exception would seem to be MT, who, at 25 months, seemed to detect the edge of the television set very rapidly. This only occurred, however, after he had touched the set (with which he was familiar). It could, therefore, have been an instance of touch teaching audition via an association of the signals. (This points to a problem when testing in the subject's home. It is possible that what appears to be an index of guide use may, in fact, be use of an already acquired knowledge of the surroundings.)

Assuming that the distinction between use of the auditory signal's guide-specific characteristics and use based on the characteristics it shares in common with everyday auditory signals can be made, there is a yet more difficult question to be answered. This has to do with whether use of the signals of the guide is "perceptual" or "operant". A theory positing initial intersensory substitutability would argue that the young organism would be able to use guide information in a manner equivalent to vision. The guide would, on this view, function as a perceptual surrogate since information picked up by the senses would be intersubstitutable. Older infants would, instead, be restricted to the use of the guide as an operant signalling device. An example may help to clarify the intended distinction. Suppose we present an object 10 cm. from the baby and 15° to his right. Suppose that over several trials the infant can come to seize the object. The question then arises as to what should happen if the object is moved to, say, 15 cm. from the baby and 25° to his left. If the guide is presenting no more than an operant signal, being used as an operant signalling device, then relearning should be necessary. If, on the other hand, the guide is giving perceptual information, that is, being used amodally, then transfer of success and accuracy should be more or less automatic and immediate. It is argued that such '<u>immediate transfer of success</u>' is a pre-requisite, within cross-sectional studies, for establishing perceptual or amodal usage of the guide.

For the older school children, we see no evidence of such response transfer. The response matching of <u>BL</u> and <u>BK</u> (8½ years and 9½ years) seems to be the best option available to them. In contrast, if we look at our younger sample we see many instances of such transfer. The accurate reaching in depth and direction of <u>SC</u> (5 months) and <u>SN</u> (8 months) attest to this. <u>SI</u> (13 months) showed accurate use of distance but, with direction, his reaching was accurate only to the sector of the object's position. One possible explanation for this may be that objects are not usually presented to blind children off the midline; it could therefore be a deficit in motor response, not in perceptual pick-up, which is responsible for this inaccuracy. The tracking exhibited by <u>AN</u> also shows a similar transfer of success.

It was also thought possible that if the subjects were using the guide in any perceptual sense, then the signal information picked up by them could be used as an aid to performance in other tasks. To test this out in the older subjects, the stacking/manipulation tasks were carried out. The results of these tasks show that performance with the guide on, rather than improving on tactual information alone, actually showed a decrement. (See Table 2.4 previously.) It appears that by this age, the children have developed a set of sensori-motor responses for coping with such tasks. These responses are specific to only one modality - that of touch. Any other information presented through another modality is again sensory specific and does not contribute to their task performance. Instead, it seems to act as a distraction, some sound that has to be listened to while carrying on with the task.

A further indication that information has become, for these children, specific to each sensory modality, is the observation of behaviour when the child grasps an object in the field of the guide. In every case of those school children who were able to use the guide to some extent, we saw a curious behaviour. It was seen that these children invariably brought the object to one or both ears. This, of course, resulted in the signal produced by the object being lost, as the object was then out of the field of the guide. In contrast, none of the younger infants did this. They explored the object, often keeping it in the midline, but without bringing it to their ears. A similar response to that of the older children is seen with subjects MT, a 25-month old boy and with BG, a 13-month old girl. It appears that for these children, sounds, instead of providing higher-order information about properties of objects, have become something to listen to. This is not the perceptual or amodal usage of the guide seen in the younger infants. Sounds, for this older group, have become properties of objects to be listened to. Sensory specification has already occurred with these subjects. They have worked out a set of sensori-motor responses for noise-making objects. For instance, objects can be picked up, shaken, rattled and taken to the ear. For these children further exploration must be done manually, to discover size, shape and texture of objects.

Bower's assertion (Bower, 1977 b), disputed by Kay and Strelow (1977), that only the most intelligent, and already the most mobile, of blind subjects can use the guide effectively, is borne out by the results with the school-age sample. Although it is a small sample, it is seen that the most effective users were BL and BK, reported by the therapist and by their teachers to fulfil the above criteria. Although able to make some use of the guide, there was no evidence, however, in these two subjects of any ability to use the guide in the 'perceptual' or amodal way characteristic of the younger infant.

CONCLUSIONS:

In summary, it might at first appear that the cross-sectional data presented in this chapter is confusing and can provide no clear evidence of any age-linked differences in ability to use the specific characteristics of the auditory signal provided by the guide. If, however, we adopt the criterion of transfer of response success, we see that different patterns emerge between our younger and older infants and children. Evidence for intersensory substitutability seems to exist for our younger infants, with their rapidity of acquisition of guide information and rapidity of response transfer. In contrast, patterns emerge in our older infants and older children which indicate use of the guide as an operant signalling device. For instance, a response-matching strategy was seen in the best user of the guide in the older sample.

While producing evidence of age differences in guide use, the results presented here can tell us nothing about the processes of development underlying these differences. They tell us nothing, for instance, about the development of reaching with the guide. Nor do they give us any evidence as to whether prolonged use of the sonicguide can alleviate the plight of the blind child. For this, it would be necessary to conduct a longitudinal study of blind infant guide users. The next chapter reports such a study.

CHAPTER 3 - LONGITUDINAL STUDY OF BLIND SONICGUIDE USERS

INTRODUCTION:

The aim of the study of long-term users of the guide was twofold, addressing both practical and theoretical problems. The practical aim was to assess the extent to which prolonged use could ameliorate and normalise the development of the blind infant. It is only by longitudinal monitoring that the effectiveness of intervention can be assessed. The amount of information obtained from cross-sectional studies is limited in many ways. Firstly, there are severe time-constraints on the testers. In the cross-sectional studies reported in Chapter 2, it was found for instance, that very few of the classes of behaviours listed in Table 2.2 which it was intended to investigate could actually be studied in the allotted time. Much of the time may be devoted to quieting a distressed or hungry baby for instance. Another problem is a problem common to all research on infants. What if an infant fails to respond in some particular testing situation? The reasons for lack of response may be that such a response is not in the infant's behavioural repertoire. That such qualitative differences in sensori-motor, cognitive, and possibly social and personality areas do exist between congenitally blind and sighted infants has already been indicated. It may equally be, however, that the testing situation is not appropriate for eliciting such a response. It could also be that the infant is too tired to display the response. Sorting out which of these alternative explanations, if any, is correct is difficult in cross-sectional studies, but becomes more possible in long-term investigations.

On the theoretical side, longitudinal studies enable conclusions to be drawn about the possible inter-relationship of behaviours. For instance, Fraiberg (1977) has shown that auditory-manual co-ordination is a prerequisite for creeping or crawling to occur. In sighted infants, the search for behavioural antecedents can only take one of two forms, one of which is ethically impossible - the sort of experiment in which a behaviour is prevented from emerging and the effect of this on the later appearing behaviour monitored. The second approach is to practise the particular behaviour which is thought to be antecedent to a second behaviour, and then to monitor any acceleration in the appearance of the second behaviour. With blind infants, we already know of some interrelationships between the emergence of behaviours. For instance, if we return to Fraiberg's example, we find that as soon as reaching to sound sources was obtained, the infant's postural readiness for creeping was converted to the occurrence of that creeping. It was hoped that these studies might uncover similar instances of behavioural interrelationships.

A further advantage of this type of study is that it allows us to look at <u>change</u> in behaviours. Developmental psychology mainly infers change from observations of particular static points in development. In order to assign different static points as truly representing stages in development, we must devote time to looking at behavioural change, considering transitions in development as well as states. With cross-sectional studies there is no opportunity to look at such processes in development. These processes can only be looked at by long-term investigation.

There are several major theoretical questions which, it was hoped, such a study would answer. The first concerns whether blind infants can use this information source. The previous chapter would suggest that they can use it, but because of the age effects obtained in that study, the question remains whether they can use it over an extended period. It may also be possible that no advance upon initial use will be obtained with prolonged exposure. It may be that the results obtained with the original baby (Bower, 1977 a) were unique and cannot be repeated. Assuming the answer to the first question is affirmative, the second question is whether the provision of guide information will offset the developmental problems normally observed in the congenitally blind. The third consideration is whether there would be any notable developmental problems incurred by prolonged guide use. The previous study (Bower, 1977 a) had attracted some anxious criticism concerning the possible ill-effects the guide might have on speech development. While in theory it was, and is, possible to shift the input range of the guide beyond that of speech, this was not done for reasons given in Appendix II. An additional criticism was that the use of this device might in some unspecified way alter the course of 'normal' social interactions for the blind infant.

METHODOLOGY:

The ideal longitudinal study would be one which lasted for approximately ten years. With this sort of time span, more accurate and wide-ranging assessment of the effects of an early intervention programme upon later development could be made. For instance, the acquisition of 'higher' spatial concepts such as that of Euclidean geometry, reported as being absent in the congenitally blind, could be investigated. The ideal study would also provide data from other infant 'controls' e.g. infants not using the guide but are the subject of some other intervention programme. (The ethical difficulties involved in this are considered in detail in Appendix I.) Neither of these ideals could be achieved within the time-span of this thesis.

The present study was constrained by a variety of factors. The distance between ourselves and the babies was one such factor. In one sense, this was not a disadvantage. The infant in the Bower, Watson and Umansky (1979) study was seen on average twice a week, with each visit lasting several hours. That degree of intervention attracted criticism. Whatever the success of the programme, it could never be cost-effective. In addition, whatever the degree of normalisation of development, the development itself could hardly be described as 'normal', in that normally developing infants just do not have infant psychologists and paediatricians watching their every move. In the event we aimed at a monthly check on infants' progress.

A second factor constraining these studies was again due to the distance involved between the infants and ourselves. This distance meant that many of the everyday questions arising could not be answered by us. In these cases there was a co-operating psychologist or paediatrician on the spot to answer any immediate queries the parents might have. While not always ideal, this proved to be a reasonable compromise.

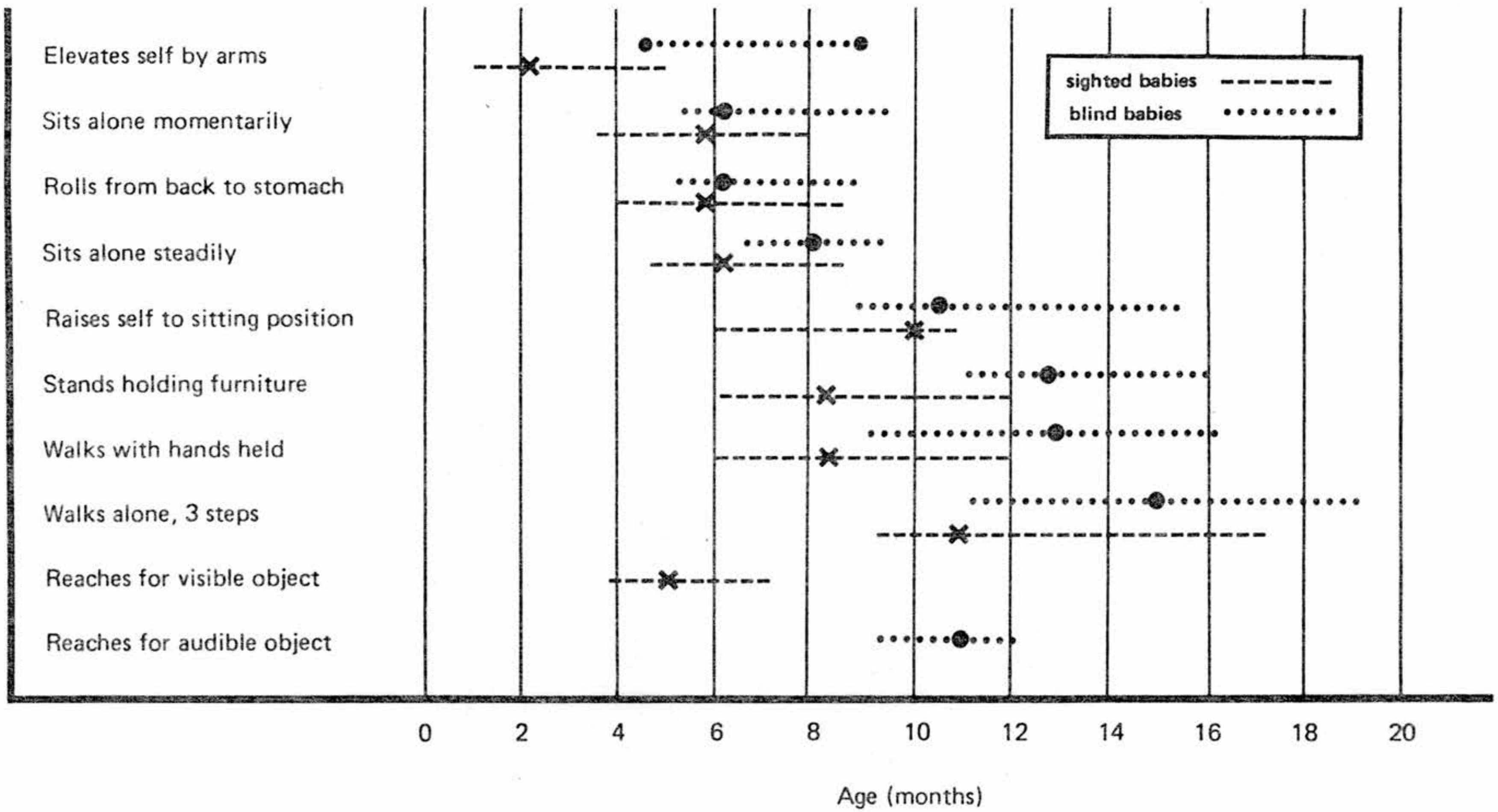
<u>Procedure</u>: Due to the possible ill-effects the guide might have on speech development mentioned above the parents were asked to place a limit on guide use. The parents were asked to aim at a minimum of two ten-minute sessions per day, with a daily maximum of two hours. Since all of the babies were awake a minimum of eight hours per day, it was thought unlikely that this would interfere with language development. It proved impossible to write detailed protocols for use by the parents. We had initially aimed at day-by-day descriptions of activities to be tried. This, not surprisingly, proved completely impossible. The parents were therefore asked to aim to do two things, one a daily feeding and social play routine, the other a daily physical test of capacities. It was felt that the former

could be left to the parents. For the latter, they were given a schedule of motor/cognitive development and asked to test the child on the items there at the given ages and thereafter. (See Table 3.1 overleaf.)

We further encouraged the parents to allow the baby to do anything it wanted while wearing the guide. The overall advice given was to treat the baby as a sighted baby, <u>while wearing the guide</u>, advice that was not readily comprehensible to two sets of parents, for whom the blind baby was their first and last child. During visits we attempted to normalise parent-child behaviour as much as possible. The main aim here was to suggest to the parents that they encourage the baby to be as active as possible. Parents of blind infants are, quite naturally, very protective. It has already been suggested that this may lead to extreme passivity on the part of the infant, passivity that may play a causal role in developmental delay (Bower, 1977 a, 1979).

Visits to the home were intended to provide information via three different methods. First was standard assessment with and without the guide. This involved presentation of audible objects or placing objects for specified times into the field of the guide and recording any search and tracking behaviours. Secondly, attempts were made at training with the guide, with objects being systematically moved in and out of the field. Thirdly, natural observation of the infants was carried out. Infants were observed both with and without the guide. Ideally a coding and recording system would

Table3・1 **Schedule of motor development for blind and sighted infants.**
(After BOWER, T.G.R. (1977). A Primer of Infant Development: San Fransisco: Freeman)



have been used, but this proved to be impossible due to the practical and logistical problems involved in making home visits. Video recordings were, however, made periodically throughout the study.

The investigation of the same classes of behaviour as presented in the previous chapter allowed for the focus of the standard assessment component of a home visit to change as the infant developed. Initially attention was given to sonicguide-hand behaviour and reaching for silent and sounding objects. Attention was then shifted to object concept tasks. Thereafter attention was also given to locomotor behaviour, both with and without the guide.

Subjects: Three infants were selected from the cross-sectional sample for long-term study. The word 'select' is slightly misleading. Selection on our part only followed a positive request for intervention from the parents. It was also constrained by the possibility of on-the-spot help for the parents from qualified professionals. The subjects selected were AN SN and BG. An additional anophthalmic infant, NN was included. Travel difficulties made it impossible to see this infant at receipt of the guide. No information is therefore available on this infant's initial response to the guide. The specific characteristics of these subjects, along with impressions of parental attitudes, are given below.

RESULTS:

Again both general behavioural descriptions and summary tables are provided. For the sake of brevity, the clinical descriptions are curtailed (for subject SN, BG and AN, see Chapter 2).

Subject SN (8 months): The parents of this infant manifested many of the familial problems associated with having a blind child. The father completely rejected the child, and, having an older daughter from a previous marriage, devoted his time to her. The mother found it difficult to reconcile her wish to care for the child and wanting to co-operate with the father. It appears that the introduction of a sonicguide was one means of reconciling this difficulty. With the purchase of the guide the father felt that he had absolved himself of his responsibility to the child, and felt that the guide could take over the role of parental stimulation in development. The mother too seemed to feel that the child would benefit most from either wearing the guide or her stimulation of the child, not from a co-ordination of the two.

Not surprisingly, therefore, SN had a rather stormy relationship with the guide. He would wear it daily only if bribed. Initial mastery of guide use for prehensile tasks was rapid. Two-handed reaching and grasping of objects on surfaces was established by nine months of age. This is slightly later than for sighted infants, but well in advance for demonstration of this behaviour with blind infants (Fraiberg, 1977). Object permanence testing was attempted with the baby at this age. The baby would attempt to retrieve a completely hidden object, but made a characteristic Stage IV error of searching for an object in the place where it had previously been found.

The next report by the mother suggested that a set-back in reaching had occurred. At 10 months the baby discovered that he could locate objects on surfaces simply by sweeping his arms from a 180° separation to the midline. This behaviour was obviously not dependent on guide use and is a strategy frequently adopted successfully by blind children (those who can reach) to locate soundless objects. This behaviour replaced accurate reaching for several months.

The next indication that the specific qualities of the guide were being used (as opposed to those qualities which are common to auditory information from sounding objects) came at 15 months of age. At this age SN was supplied with a babywalker. When in the walker he was content to wear the guide up to the maximum of two hours. During this time the guide information was used to control his movement. When approaching objects, the infant would raise his feet to stop himself banging into the barrier. Use of the guide in this way proceeded for several weeks until the infant was able to accurately locate objects in the house. During this phase of use, the guide was seen to be used primarily for prolonged foot inspection, analogous to the 'hand regard' seen in sighted infants. During this phase the infant would also reach for and manipulate objects while wearing the guide.

His performance on object concept tasks did not improve. By 20 months of age the baby could navigate around his home in the walker, with or without the guide, and he increasingly preferred to do so without. At this point guide use fell back to a minimum.

Use only recovered when the infant began to walk when held or while holding on to surfaces. This phase of locomotion was accompanied by use of the guide for the maximum period as before. He appeared to be using it to get information when approaching objects and for surface/edge detection. This phase of locomotion was proceeding rapidly when the parents, misunderstanding the diagnosis and report of an American eye surgeon, became convinced that sight restoration surgery was possible and discontinued guide use. The child was seen by us several months later, at which time surgery had, as yet, not been performed.

There follows a brief description of behaviour observed at this stage.

The subject was very difficult to work with, was uncooperative and did nothing for himself, as there was never an opportunity, nor a need to do so. He was characteristically over-protected. Some evidence was found for residual vision in that he defended himself to an approaching object and showed convergent eye movements to an approaching object. A few reaches were observed in the right visual field, and he once possibly imitated tongue protrusion. He would only engage in eye contact if forced to. No reaching was obtained to noise-making objects, nor would he track these. No locomotion - walking, creeping or crawling - was seen until he was chastised. Then he took three clumsy, splay-footed steps to one of the testers and cried bitterly. Vocalisation was poor, it being difficult to extract anything other than a series of whines, although on one occasion he imitated one of the testers verbally. No speech production was observed.

In many respects development, in the months since guide use had ceased, appeared to have either stopped or to have regressed to that of a period many months prior to this session. In addition, no surgery has as yet been performed.

Subject BG: This child hardly tolerated the guide after the initial testing session. She was found to cope with her normal home environment without it, in a very competent way. While she is navigating around her home, it is hard to tell that she is blind. Typically, no new obstacles are presented in her path for her to discover. The same is true in feeding or play situations, where no games have been initiated which would necessitate, and thereby possibly promote, guide use. At this time - the child is now 4 years old - the parents are unwilling to place the child in any novel situation where the guide might be of use. It is possible that this may change in the future.

Subject AN (6 months): The parents of this child, the youngest in the longitudinal sample, were well-adjusted to the demands of a blind child. They had a distrust of medical intervention, preferring to rely on their own intuition and to do things on their own. Occasionally this attitude transferred to the sonicguide which they may have initially accepted as being a panacea, not requiring their simultaneous intervention.

AN wore the guide on a daily basis without protest. Her reaching and grasping developed along the lines of a sighted infant. Two-handed reaching began at seven months. Placing on approach to a table surface occurred at nine months. She was tested on object concept tasks at ten months. She was observed to be able to retrieve an object partially hidden by another object, but failed to retrieve a completely hidden object. Failure occurred with tasks equivalent to Piaget's Stages IV, V, VI. At eleven months, the Stage IV/V transition task was passed, with the Stage V/VI tasks producing failure. On the next and subsequent visits the infant would not co-operate in these tests. This can be a problem with sighted infants as well.

A report by the paediatrician indicated that crawling commenced at 14 months and independent walking at 16 months. At 19 months, while moving round her home wearing the guide, the infant would spontaneously seize or touch objects, naming them only after touching them. No naming could be elicited prior to tactual discrimination. Some evidence could be found for discrimination of objects by guide alone. The evidence for such discrimination was that if left to herself, the infant would seize or touch soft objects rather than hard ones, and graspable surfaces, such as curtains, rather than ungraspable ones, such as windows. When tested at 23 months by a specialist in language development, the infant's speech was reported as being precocious even by the standards of a sighted infant.

Several months later, on the basis of two sessions of observing the child using the guide, the child's paediatrician decided that the attention given to the guide was interfering with the child's development as a 'normal' blind child. She advised the parents to terminate sonicguide intervention. They did so.

Since then the child has been seen by us on three occasions. Development appears to have proceeded well. Her speech comprehension and production appears to manifest none of the peculiarities reported in other blind children (Clarke, 1978). She appears to have no trouble with the first person singular, 'I', using it appropriately and vociferously in her demands. She has well-established games to play with her mother, into which strangers are immediately accommodated. No blindisms were observed on any of these visits, nor were they reported by the mother. Her orientation to sound-making objects, both familiar and unfamiliar, was very good, locating and grasping them almost immediately. Similar successes were observed with objects which were systematically dropped on various surfaces. She could accurately name and locate all the parts of her body when asked to, and when sticky tape was attached to the surface of her skin, she was able to immediately locate it and pull it off.

A variation of a task used by Hatwell (1966) was presented to her. The task used by Hatwell involves presenting the subject with several objects in different spatial relations to each other. Having felt the objects, they are then disarranged and the subject asked to position the objects in the same spatial relationships to each other as before. Results show that congenitally blind children are significantly poorer than adventitiously blind children in this task. In this study, AN was presented with three objects and then asked to reproduce their configuration. She did this successfully on two occasions. Thereafter she became bored and insisted on playing her own, more imaginative, games.

Subject NN: This infant was born with cancer of both eyes. At one month of age one eye was removed and six months later the other was removed. It was reported by the hospital that in the intervening months he may possibly have had minimal light perception, although this was doubtful. This was supported by the mother's report that she first knew something was wrong when the baby was 2-3 weeks old, although she did not know what. The parents were quite optimistic about the child's future, possibly unrealistically so in view of their geographical isolation. They appeared to treat the intervention with the guide as a sort of game which psychologists were playing; they were quite content to look on but were very doubtful that any significant gains might result from its use. NN had first been introduced to the guide at 14 months of age; at the time of our visit he was 18 months old. In the four months he had had the guide, use had been sporadic; there had been no continuity in type of use and little or no attempt at any structured training.

On our first visit the child sat well, but could not stand, crawl or walk. Reaching to noise-making toys was accurate as to sector only; no improvement was observed after practice. No defensive responses to approaching audible objects, or reaching to them, was observed. Attempts at testing object concept produced a pass at Stage III, but a failure to find an object covered by a cloth. With the guide on, after several trials of objects approaching in the midline without contact, one defensive response was obtained. This response consisted of the hands being interposed between face and the approaching object. No tracking was observed. Placing to the floor again produced no guide-specific response. A blindism of rigidly holding the hands behind his back during placing appeared to be interfering with any possible elicitation. On this visit then there was no evidence of guide-specific responses, with, in fact, there being little evidence of any improvement at all while wearing the guide over behaviour shown without it.

On a subsequent visit made shortly after, no improvement was observed in the responses tested while not wearing the guide. In order to check on any awareness of his own body, adhesive tape was attached, in turn, to various parts of the anatomy. Few attempts were made to remove the tape. On the occasions when attempts were made, they were mostly unsuccessful in locating the tape. No vocalisation other than humming was obtained.

The infant appeared to be largely indifferent to the guide while wearing it. On first wearing it, he rocked back and forth pointing to the ground (this was not observed while without the guide). Over many trials, only one reach and grasp was obtained, with no evidence of anticipatory hand-shaping. As soon as he had grasped the object, he dropped it. No attempt at search or recovery was seen. No radial tracking was observed. No signs of familiarity with, or recognition of, objects was shown when using only the signal from the guide. Extensive attempts at placing to several surfaces and edges produced the beginnings of one response, to a table edge. It was unclear whether the full response was not obtained as a result of the blindism mentioned above. Attempts at social interaction and game playing met with failure. (Smiling was only observed during games ending in full contact with the infant. The smile appeared to be characteristic of the blind child - Dunkeld, 1978). No search behaviour was observed with objects brought into and out of the field. Stage IV of object concept was passed on one trial. It was felt, however, that the large number of trials necessary before success was achieved in recovering the completely hidden object detracted from its significance. The task was repeated with a different object and occluder: this produced failure. Attempts at locomotion succeeded in obtaining three independent, though clumsy and hesitant, steps. The mother was surprised by this, never having observed any independent locomotion, and believed that attempts to have him walk were premature. The infant then became distressed and testing was terminated.

Table 3.2 summarises the responses reported above in the subjects using the guide longitudinally (see over).

DISCUSSION:

The long-term studies do not permit any easy generalisations. Because of this the discussion will focus on the implications which can be drawn by comparing and contrasting the results for each of the infants. Firstly, though, a problem arises, a problem which first arose with the cross-sectional study in the previous chapter. This again has to do with the adoption of our criteria for determing use of the guide. Previously, it was argued that one criterion of use to be adopted should be immediate transfer of response success. This criterion is valid for cross-sectional study of guide use. It is also a necessary condition for long-term assessment. It is, however, not a sufficiant condition for determining whether use in long-term subjects is perceptual

Table 3.2 Summary of responses of infants in long-term study

Subject	Behaviours						
	Reaching	Placing	Object Permanence	Crawling	Walking	Object Discrimination	Other
AN	Two-handed (7 months) Then on a sighted schedule.	At 9 months	Stage III Pass at 10mth Stage IV/V Pass at 11mth Stage V/VI Fail.	14 months	16 months	Texture discrimination of soft v hard objects.	At 23 months speech development precocious without guide. With guide names objects only after touching.
SN	Two-handed grasp of objects on surfaces 9 months.	At 9 months	Stage IV Fail at 10 months		15 months Babywalker Used guide to approach barriers and stop.	Picked up single object from among several and grasped objects on surfaces	Increased use with emergence of new behaviours.
BG							Copes without guide competently. Is not placed in novel situations which might promote guide use.
NN	One-handed inaccurate in depth.	Not appeared at 18 months.	Difficulty in testing.		Not emerged at 18 months with or without guide.		

or admodal in nature. It is possible that operant rather than perceptual use could underlie any apparent transfer of success to new situations when use is spread over a long period. Consider the example of reaching. If many instances of objects in differeing positions were experienced by the subject, it is possible that a large number of quite specific responses could be built up enabling apparent response transfer when 'new' object positions were tested by the experimenter. Any such success would be achieved on an operant rather than a perceptual basis. Transfer of response success is therefore an insufficient criterion for guide specific use in long-term users.

If, however, the guide _is_ being used as a perceptual surrogate, in a manner formally analogous to vision, we would in addition expect the infant to develop along the lines of a sighted infant, not a congenitally blind infant. This requires that the guide be used like vision to promote and/or to establish new behaviours. In addition to response transfer, then, it is argued that a second criterion of perceptual usage should be the observation of the emergence of new behaviours, behaviours that would not otherwise be observed with the 'normal' congenitally blind infant in its development. It is argued that it is essential to adopt such strict dual criteria of usage in order that an accurate assessment may be made of the manner in which the guide is being used. No assessment of a theory of differentiation in development may be made without the adoption of these criteria of immediacy of response transfer and emergence of new behaviours.

To put the results obtained above in context, it is worth recalling the results of the large-scale study of adult guide users who used the guide on a long-term basis, mentioned in Chapter 1 (Kay, 1974). Kay reports that actual training time required was up to 70 hours, with: "most subjects grasping the concept within about three to four weeks". The total training period varied from several weeks up to six months.

The adults in Kay's study could make little effective use of the information provided by the guide. In particular, they were unable to discriminate edges, which meant they could not use the guide for locomotion, nor could they detect apertures such as open doors. (A discussion of the psychophysics involved in these problems is given in Appendix II.) By contrast, the cross-sectional infants described in Chapter 2 showed age-appropriate use, within minutes for the younger ones and after only a few hours for the older ones. Neither edges nor doorways were problems.

If, however, we look at these cross-sectional results in conjunction with the results of the present long-term study, we see that thirteen months appears to be an upper age limit for any rapid acquisition. After this point, the results compare with the results of the Kay study. Marked differences between infant and adult users are seen in ease of transfer of response. Kay's study emphasises the importance of a slow gradual build-up in training, with laborious re-learning being required before appropriate responses can be transferred to new stimulus inputs. In contrast, the young infants described here and in the previous chapter demonstrated almost immediate transfer of response. Moreover the youngest longitudinal subject, AN, demonstrated emergence of new behaviours on a par with that of sighted infants. Kay does not mention the emergence of new behaviours in his subjects, possibly because he does not regard this as a criterion of use. If not, he provides no alternative criteria, with his only allusion to the need for one being that: "a theory of mobility has yet to be evolved" (Kay, 1974, p. 606). Kay also emphasises the importance for long-term users to utilise a priori information, information such as the knowledge that when the subject comes to a road intersection, the signal received is most likely coding for a traffic light rather than anything else. The blind infant can have little a priori information which makes their ability to use the guide, when compared to that of the adult, even more remarkable.

However, as has been pointed out above, there was a great deal of variation in the responses of the long-term subjects in the present study. It is to these variations that we must now turn. AN, the youngest infant, did indeed develop on a sighted rather than a blind schedule. Table 3.2 shows this for the emergence of two-handed reaching, placing, crawling, walking and speech development. To this extent the guide was successful as a surrogate and fulfilled the criteria of perceptual usage. The results obtained with this infant do indeed fit into a differentiation theory of development with the infant apparently being able to 'latch on' to the auditory equivalent of visual information provided by the sonicguide. This infant was first provided with the guide at a time when information pick-up was truly amodal. The information provided through one sense (audition) was substitutable with that normally provided through another (vision). It is too early to say, as yet, whether the distal information about objects and events provided by the echoic signals during infancy can offset cognitive lesions in spatial abilities normally observed in blind subjects in later life. The results of the version of the Hatwell (1966) task (presented to the child some time after ceasing to use the guide) do suggest this possibility. However, with the results of only one subject it would be premature to state that echoic spatial information presented in infancy can lay the foundations for later abilities required in spatial tasks such as Euclidean geometry.

The other infants, although less successful in their effective use of the guide over a long period, are on closer analysis just as informative. Consider BG. There has been no evidence of guide use since the initial testing session and she can cope with her normal home environment without it very well. The reason for this may be seen if we consider this child's use of the guide in the initial session. It will be recalled that this infant persistently brought silent objects from the field of the guide to her ear, where of course, the object produced no further signal. In the adult study previously cited, Kay himself states that for the sensory aid and natural perception of space to be matched, then the impression of the user should be: "that objects in the environment were themselves making the sounds" (Kay, 1974, p. 620). This is precisely what was observed with BG. It appeared that with sound becoming a property of objects, it no longer afforded a medium for perception. The two had become quite separate. It would appear that with sensory specification having already taken place, this militated against guide use. It would appear possible, too, that the guide, rather than affording possibilities for prediction and control, actually contradicted the rules by which this infant was by then understanding his world. This infant had a set of sensori-motor responses related to noise-making objects - taking to the ear, shaking, etc. These did not work in the new world of the guide. Under such circumstances it is not surprising that guide use did not take off.

It is possible, however, that given a particular set of circumstances, guide use could have taken off in BG, on an operant rather than amodal basis. Such a set of circumstances would have involved use of the guide in novel situations, encouraging active control over its signal input, and making use of the guide in structured training situations. None of these situations ever arose for BG. The parents did not, for instance, provide novel situations to cope with where the guide could have been of value. With little to be gained for the child, it is hardly surprising that guide use did not take off on an operant basis either.

Subject NN manifests many of the same problems as BG. Guide use appears to have been implemented too late for any use as a perceptual surrogate. The programme of intervention necessary to allow use on an operant basis was also lacking. As Ferrell (1980) has argued, the most important contributors in any intervention programme are the parents. For the programme to be successful, it is necessary that the parents believe in its efficacy. The parents in this case did not have such a belief. Consequently, situations which might have promoted guide use were not created. It may be thought that advocating the need for such a "belief" is neither scientific nor objective, since it requires us to prejudge our "experiment". There are, however, advantages to be gained from doing so; it optimises the chances of success with our intervention and also gives the parents something tangible with which to encourage stimulation of their child. This approach need not obscure the scientific merit of these studies. The criteria of use outlined previously are not subject to such a criticism. We can therefore retain an accurate assessment of guide use, while coupling it with what should be the optimum intervention programme, thereby allowing both practical and theoretical assessment.

In many ways the results obtained with SN are perhaps the most suggestive and informative of all. He initially demonstrated a rapid advancement in reaching, similar to AN, and then this dropped out. The same occurred with his locomotion - both with and without the babywalker. At the beginning of each of these activities, he used the guide a great deal and then, once the behaviour had been established, guide use dropped off. In his case the emergence of new behaviours seemed to promote guide use. Only in the emergent phase of a new behaviour was there protracted guide use. Once the behaviour had been perfected (or schematised) the use fell off.

Explanations for this based on either an extreme nativist or extreme empiricist position cannot be upheld. In the case of the nativist view, the emergence of new behaviours should be sufficient for their perfection and establishment. That they were not established without guide use would at first appear to support an empiricist account of development. However, that environmental input is necessary but not sufficient is shown by NN whose motor development is now retarded, despite prolonged guide use at a later age. Instead it would appear that we must accept an epigenetic account whereby new behaviours may emerge at particular ages, but without the support of environmental information such behaviours cannot be established. This information, whether it be provided by light or by a sonic field, must come at the right time for behaviours to be functionally established by the organism. These results would seem to support the Piagetian idea that behaviour is the motor of development (Piaget, 1978), with emerging behaviours "demanding" perceptual aliment. The "demand" would appear to be for the kind of information provided in light or by a sonic field.

Since guide use was terminated, SN has been unable to stabilise any new behaviours. A question which arises from the results with SN is why, if guide use was high in the emergent phase of a new behaviour, did it then tail off? If the guide was providing information which the infant could meaningfully use, then why did he stop using the guide once the behaviour had been established? An instance of this is seen in SN's adoption of the typical "blind child's" strategy of sweeping the arms to locate objects in front of him - a behaviour that clearly does not demand use of the specific information qualities of the guide. A possible explanation can be given if we consider the similar results obtained with the first blind baby ever to use the guide, DD (Bower, Watson and Umansky, 1979). It was reported that that infant was quite unwilling to wear the guide after several months of successful guide use. While both DD and SN would wear the guide when placed in a novel location, unwillingness to wear it was manifested in their own homes, where the majority of the day was spent in one room, with a small range of familiar objects to manipulate. It seems that on the former occasions, involving novelty, there were large gains to be made through wearing the guide. On the latter occasions the gains in information from wearing the guide were small, as these involved familiar, already explored events. If, in addition, we recognise that there are certain disadvantages to be incurred in wearing the guide we can see the explanation for drop off in use. The guide was uncomfortable to wear. It also masked some of the ambient auditory information from other sources. It seems plausible then that both of these babies wore the guide, despite discomfort, when it could provide information about novel events. In a very familiar environment, there was little gain in information and greater cost involved in discomfort. A simple trade-off in terms of costs and gains to the infant could therefore explain the drop-off in guide use observed. This too is supported by the observations of BG who was given no opportunity to use the guide in novel situations. There were no gains for her in wearing the guide and consequently perhaps, she made little or no attempt to use the guide.

A further point which arises from this set of studies concerns the degree of intervention mentioned in the introduction to this chapter. It was suggested that the achievements of the first baby, DD, (Bower et al, 1979), could have been due to the intervention *per se*, i.e. some form of Hawthorne effect. The results obtained with AN and, to a lesser extent, SN, who had far less time spent by psychologists and others in intervention than DD, are an empirical disproof of such a statement. Such an argument in any case begs the question of *how* these changes through intervention came about.

Unless we can predict on which behaviours the baby is going to advance, predictions which can only be encompassed within the framework of a theory of differentiation and using the criteria of use outlined, we will have no idea about how the behaviours interrelate and what stimulus parameters the infant is picking up from his environment.

In similar vein, a criticism could also be levied that it is possible the infants seen in this study represent one extreme of blind infants, in that their parents were willing to go to great lengths to provide a better chance for their child. This determination would, it follows, be carried over to the general amount of stimulation given to their infant. With lack of stimulation playing a possible causal role in developmental delay (Seligman, 1975), it would be this general attitude, rather than the sonicguide, which ameliorated development. However, there was no single reason common to the parents of the subjects described here for wishing long-term guide use for their infants. There were many possible reasons for take-up of the offer of protracted guide use, reasons which have been discussed for each subject. One, at least, of these reasons (<u>SN</u>) was consonant with there being no associated increase in general amount of stimulation given to the infant. There are, moreover, many blind infants whose parents do provide them with a very high level of general stimulation but who nonetheless still develop along the lines of the typical blind infant. It seems to be the co-ordination of guide use with this stimulation which enables development to proceed on a sighted schedule.

CONCLUSIONS:

In practical terms, the foregoing results suggest the advantages to be gained by early intervention with the guide. The guide has been shown to be useful in alleviating the plight of the blind child. Implications for general theories of development can also be drawn. The validity of a theory of initial intersensory substitutability with amodal pick-up of information has been upheld. The results also support the suggestion that intersensory differentiation then occurs, giving modality specific pick up of sensory information.

Nevertheless, the results obtained are by no means clear-cut. As is to be expected when working with a handicapped population the sample size is very small. The research problems involved in this type of work are many and varied (see Appendix I), and many of them were not anticipated before embarking on this longitudinal study. There are therefore many problems which are left unanswered. These include identification of the age at which sensory differentiation occurs. There is additionally no evidence so far as to the difference in pick-up of information from sounding objects and guide specified objects. These questions can only be answered by a more straightforward, experimental approach, an approach which is not open to us when working with blind infants. The next chapter will therefore address itself to these problems by experimentation with sighted subjects with whom blindness is simulated.

CHAPTER 4 - CROSS-SECTIONAL STUDY OF SIGHTED SUBJECTS USE OF THE SONICGUIDE

Evaluation of the parameters and possibilities of intersensory substitutability requires a rigour in experimental methodology and procedure which cannot be achieved when working with blind subjects. The emotional problems and other problems which affect the running of such a project are discussed in Appendix I. Research with any handicapped group usually necessitates a compromise between experimental rigour and a clinical approach. The adoption of strict criteria in assessment of guide use has been argued for in the last two chapters, and this certainly goes some way to redressing the problems of evaluation in a blind sample. Nevertheless, in order to test more precisely the extent, nature and limitations of intersensory substitution it is necessary that more and better controlled experimentation be done than is possible with blind subjects. In addition, there is the obvious problem of the lack of availability of sufficient numbers of blind subjects within a small geographical area - fortunate for society but unfortunate for the researcher.

Blindfolded sighted subjects or sighted subjects in darkness would appear to provide an option for the researcher which avoids the above problems. Comparisons cannot always be easily drawn between results obtained with simulated blind subjects and actual blind subjects. Many experiments have shown that blindfolded sighted subjects do not perform in the same way as blind subjects (e.g. Hatwell, 1966; O'Connor and Hermelin, 1972; Spigelman, 1976). However, there were theoretical reasons which justified using sighted subjects to simulate blind users in testing the predictions of the various theories of perceptual development considered in Chapter 1. For example, if infants initially respond to specific sensory stimulation we would expect no use at all of the guide in young sighted infants. For these subjects the sounds produced by the sonicguide would merely be something to be listened to, having no informational value. Secondly, young subjects are at an apparent disadvantage in any test for ability to make use of the guide in that we cannot communicate to them the meaning of the signals produced by the guide. It could be that by providing older subjects with verbal instructions we could get them to use it to some degree. Thirdly, it could be that as adults are already using such information as distance, direction etc., they might be able to transfer use of such information to the guide situation, as it provides formally equivalent information. Use of sighted adults therefore bypasses the problems of spatial understanding known to exist in older blind subjects; as the older sighted subjects already have these concepts it could be easier for them to transfer them to use with the guide. Fourthly, is a point which is related to the previous one: sighted adults have a distinct advantage in that they can control visual input, control which blind subjects do not possess, being limited to the role of passive recipients of auditory input. The guide also enables control of the input of information about objects, events and space. Sighted adults could therefore show transfer of the use of this control and be able to use the guide to greater effect. All four of these reasons would maximise the chances of finding evidence for intersensory substitutability in adult subjects. If adults showed a greater facility in guide use than younger subjects, we could then discount two of the three differentiation theories of perceptual development.

It could also be predicted that no differences in use of the guide would be shown among various age groups of sighted subjects. This could be accounted for by the fact that we live in a vision-dominated world; for the sighted, the greatest amount of information we receive comes through vision. Similarly, it may be that the reason older blind subjects cannot use the guide is because they have worked out a set of responses for 'normal' auditory objects. The guide does not conform to this 'normality', as it is an entirely novel sensory input. If these two related hypotheses are true then we might expect to see little or no difference in guide use across various age groups of subjects.

For the above reasons it would seem to be theoretically and practically justified to investigate sonicguide use by sighted subjects. We have two theories that predict that use of the sonicguide by infants will be, at best, equivalent to adult use and, at worst, less than adult use. The two differentiation theories (Werner and Bower) would, on the other hand, predict that younger subjects would be better able to use the guide. They argue that the young infant does not live in a sensory-specific, vision-dominated world, but in a perceptual world in which it picks up and responds to the supramodal or amodal properties of information about objects and events. The signals produced by the sonicguide, in this perceptual world, would not be picked up in specific sensory terms but amodally. The guide is not novel in evolutionary terms if the perceptual transducers which have evolved at first function to pick up abstract amodal properties such as position and change of position. If this is the case then we would expect that the young infant would show a greater facility in his usage of the guide than the older subject.

In light of the above, it is therefore necessary to look at a wide range of ages of subjects. This study therefore looked at a sample of adult subjects, a sample of young school-age children, a sample of pre-school children and a sample of infants ranging in age from one week of age to twelve months. For ease of reporting and drawing of comparisons, these cross-sectional groups are treated in four separate sections - A, B, C and D respectively. The major problem with such an experiment is the selection of a task which has equivalent demand characteristics for all age groups. The range of behaviours seen in young infants is not large. Selection of a behaviour which is demonstrable with neonate subjects is therefore difficult. It was decided to use a search and manipulation task. Search would involve scanning, reaching, grasping and manipulation. For the subjects other than infants, a stacking task was also incorporated which involved either stacking three large blocks one on top of the other in decreasing size, or combining the two halves of a Varooshka doll appropriately.

In using a search task we will be biasing the odds against the possibility of finding evidence for lack of perceptual differentiation in early infancy. This is due to the difficulty reported by others in obtaining neonate reaching. It is still a matter of some controversy as to whether neonatal reaching in fact exists (e.g. Ruff and Halton, 1978). Discussion of neonate reaching will be left until Section D of this study. If it is difficult to elicit neonate reaching under normal conditions, it could be argued that it would be impossible to elicit it under the abnormal conditions experienced with sonicguide specification of the object to be reached for. This would be the argument proposed by any theory other than a theory of differentiation in perceptual development. According to differentiation theory, however, the undifferentiated young infant will not experience the signals of the sonicguide as abnormal because these signals retain the higher-order properties of information which are presented through vision. Young infants would therefore be capable of using the guide in the search task in a manner equivalent to vision.

It was decided to observe the responses of subjects to normal noise-making objects as well. Sounds from audible objects do have a systematic relation to what is going on in the world. They present information as to direction and change of direction and loudness bears some relationship to distance and change of distance. However the information from audible objects lacks most of the formal properties of that from vision. The sonicguide, in contrast, presents formally equivalent information to that of vision. Evaluation and comparison of responses under conditions where the sound is presented by the guide versus sound produced by a more 'natural' means will go some way to elucidating the nature of any process of differentiation. Few systematic studies have as yet been carried out to look at infant reaching to an auditorily defined object (Bower and Wishart, 1972; Haith, 1969; Wishart, Bower and Dunkeld, 1978). The results of this part of the study will therefore also be relevant to theories of auditory localisation and theories of the development of auditory-manual co-ordination.

It will be necessary to compare the results obtained under these two 'abnormal' reaching conditions with those obtained where the search task is carried out under visual conditions. Particularly with the infant subjects there is a need for baseline comparison of responses; accuracy of reaching in normal conditions in the neonate may be as low as 40 per cent (Bower, 1974). According to the predictions offered by a differentiation theory, we should observe equivalent responses in all three conditions (light, dark without guide, dark with guide) with the undifferentiated organism. The other theories would predict that at best the infant would show the same performance in guide use as an older subject.

A. Sighted Adults

INTRODUCTION:

The first group of sighted subjects investigated in an attempt to assess the nature of intersensory substitution was a group of adults. The only previous sonicguide work done on sighted adults was the introspective evidence obtained by Kay and his colleagues (Kay, 1974; Kay and Strelow, 1977). With the results they obtained they proceeded to modify the engineering parameters of the sonar aids assuming that their own use of the guide would correspond with that of blind users. No controlled psychological experimentation has been performed on sighted adults to determine the possibility, nature and limitations of intersensory substitution with the guide. Although the blind work reported in Chapters 2 and 3 suggests that the guide can only act as a perceptual surrogate in an undifferentiated 'perceptual system', that is, in early infancy, controlled experimentation with sighted adults is necessary before any more definite conclusions about the age parameters of guide use can be made. To this end, a group of adult subjects was run, first in a search task and secondly, in a manipulation task.

The introspections of Kay and his co-workers were carried out with the subjects already having a great deal of prior knowledge about the workings of the guide. If we anticipate Section D of this chapter, the investigation of guide use by sighted infants, we realise that we cannot present instructions to pre-verbal organisms. If we wish to present a task to adults which is equivalent to the infant task, we should therefore have one group of adults who receive no information about the guide prior to the experiment. It should be noted that the results of such an investigation could also have practical benefits for the training of blind adult guide users. At present it is difficult to determine how much information about the signal mix should be given before use and how much should be found out by the users themselves. It may be that very general instructions are of more use than a set of specific instructions. In order to investigate this, the adult subjects were divided into three groups:

(a) <u>High information group</u>. This group received full instructions as to the nature of the guide, what the signals code, the engineering and psychological theorising behind the guide and the control aspects of the guide.

(b) <u>Medium information group</u>. This group were only told that the mixture of signals from the guide coded for various properties of objects such as size, distance and direction. They were not told what the relation of signal to each specific property was e.g. that pitch coded for distance.

(c) Low information group. This group were given no information about the nature of the experiment or the guide.

METHODOLOGY:

The design, apparatus and procedure adopted with this subject sample are similar to those adopted for the subject samples of the next three sections. The methodology will therefore be explained in detail in this section and only differences in methodology will be reported in later sections.

Subjects: Twelve adult subjects were randomly assigned to one of the three experimental groups with an equal number of male and female subjects in each group. Subjects were all third year Child Psychology students.

Design: For the search task, each subject was given three conditions.

Condition A was presentation of a visible object. This acted as a baseline for comparing reaching - frequency, duration, latency, reaching which ended in grasping, handedness etc. Presentation lasted for 30 seconds.

Condition B involved blindfolding of the subject and presentation of a noise-making object. While providing some of the characteristics of the guide signal and producing sounds which bore a systematic relation to what was happening in space, Condition B did not provide for any means of control of that sound. Nor did it provide information as to size or shape, whether object location was in front or behind, or how far away it was. Presentation of the audible object lasted 3 minutes.

Condition C was again conducted with the subject blindfolded. This time the sonicguide was worn. Care was taken that the cloth acting as a blindfold did not cover the subjects' ears. This condition, also lasting 3 minutes, would provide all of the information of Condition B as well as information about shape, size, azimuth position and so on. In addition, it allowed the subject to control the information presented in the signal.

Apparatus: The experiment was carried out in an empty room measuring 4 m x 3 m x 3 m. The same object was used throughout, a fluffy, yellow duck, measuring 10 cm high x 10 cm at its widest point. This object was presented in one of three positions - midline, 30° to the right, and 30° to the left. If the object was successfully seized three times, it was moved to one of the two other positions. (For the manipulation/stacking task, three conditions were again run - light, dark without guide, dark with guide. The objects used were again the parts of a Varooshka doll.) The duck was attached to a thin steel rod, 1 metre long, which hung down from the end of a steel boom. This enabled no object to be present in the field of the guide other than the duck. The duck was eviscerated to allow implantation of a small speaker (impedance of 8 ohms) for use in Condition B. The speaker was connected to a Pye reel-to-reel tape recorder and the volume set at a constant level. The noise coming from the speaker was of a duck quacking. This was pre-recorded so that two quacks were emitted per second. Responses were recorded on a Sony V.T.R. using high-density half-inch video tape. The camera was set facing the subject so that head and eye movements as well as reaching responses could be recorded. A stop-clock was used to determine the end of each condition. For the stacking task, a Varooshka doll was used.

Procedure: Subjects were seated on a standard chair without armrests and, for Conditions B and C, blindfolded. The object was then swung in on the boom. At the end of each condition, the object was swung back to a position where it could not be seen by the subject. The time period began as soon as the object was in position and the tape-recorder switched on for Condition B, or the guide switched on for Condition C. The object was always presented within reach of the subject and at no time was it more than 2 feet from the subject's head. If the object was successfully contacted three times, i.e. touched by any part of the hand, its position was changed.

For the stacking task subjects were seated at a table and asked to place the small doll inside the bigger doll.

RESULTS:

Results of the search task are presented in Table 4.1.

Table 4.1 Responses of sighted adults on search task across three conditions
A Light; B Blindfolded (audible object); C Sonicguide

CRITERIA	HIGH INFORMATION									MEDIUM INFORMATION									LOW INFORMATION								
	LIGHT			AUDIBLE			GUIDE			LIGHT			AUDIBLE			GUIDE			LIGHT			AUDIBLE			GUIDE		
	L	MID	R	L	MID	R	L	MID	R	L	MID	R	L	MID	R	L	MID	R	L	MID	R	L	MID	R	L	MID	R
Reaches ending in contact	18	18	18	17	18	17	2	4	5	18	18	18	18	18	18	1	2	-	18	18	18	17	18	17	-	-	1
Mean latency of first reach (secs)	1	1	1	15	18	20	-	125	-	1	1	1	25	20	10	110	95	-	1	1	1	80	40	20	-	-	170
First reach errors	0	0	0	62	20	50	-	100	-	0	0	0	58	15	40	100	100	-	0	0	0	74	46	76	-	-	100
Total arm extension	18	18	18	31	30	39	6	8	9	18	18	18	41	30	28	3	5	-	18	18	18	36	30	22	-	-	2

If we consider only successful reaching (reaching which ended in contact), then there appears to be no difference between the conditions using a visible object, an audible object or an object specified by the sonicguide. Nor is there any difference in performance within each group, despite differences in information given. On the surface this would seem to suggest amodal use of the guide by adults, a finding in contradiction to differentiation theory. On a more detailed analysis, however, we see that this conclusion is not merited. It should be pointed out that none of the subjects in the 'low information group' demonstrated any use of the guide at all at first. All 'froze' in the test situation, four of them putting their hands to their ears. To counteract this, the experimenter had to tell all of them that the signal in their ears was giving them information about events in their immediate environment. Thereafter, the only subjects who made any arm extensions in the sonicguide condition were those who had first been given both of the other conditions. In effect then, this group was no longer comparable to infant subjects in that they had been given some information about the nature of the guide. This was necessary in order to obtain any response at all to the guide condition.

Other more empirical reasons for discounting amodal use of the guide in these adult subjects can be seen when we look at a breakdown of the reaching itself. Firstly, we see from Table 4.1 that there is a large difference between the conditions in latency of the first reach to the first object position presented. In all three information groups, latency of the first reach is much greater in Condition C than in Conditions A and B. Secondly, if we modify the criteria of reaching to include arm extensions (i.e. reaches which did not end in contact with the object), we see that the effect of condition is far greater than the effect of the previous information given to the subject. Analysis of variance (with latency scores averaged for position of object) showed that condition of presentation was significant at the $P<.001$ level. There was, however, a slight interaction between amount of information given and condition, so that those in the 'low information group' performed poorest of all in Condition C.

Although it appears on some quantitative analysis that we can discount amodal usage of the guide, it may be that there is some other reason for the adults not showing guide use. It was mentioned above that the 'low' group seemed to 'freeze' in the experimental set-up. Perhaps it is simply this freezing-up of the subject which contributes to poor response with the guide. To test this we must therefore look more closely at the responses of those who did show some success in the guide search task. We would expect those reaches, if amodally based, to be accurate and end in contact with the object. If we look at first reaches with the guide (collapsing 'information groups'), we see that the percentage of first reaches ending in error was 100 per cent. The position the hand was in when the reach ended its initial trajectory was taken as a measure of error.

It may be argued that this criterion of error is too strict and does not allow for any re-calibration within the reach. A less strict criterion was therefore looked at. This looked at the direction in which the hand was moved at the end of the first trajectory of the reach. With re-calibration, the hand should move toward the object. If the hand moves away from the object or is stationary then no re-calibration can be occurring. If the subject has been told that there is an object "somewhere out there" then we would expect random searching patterns i.e. 50 per cent hand movements toward the object and 50 per cent away from the object. Of the 33 arm extensions in Condition C (see Table 4.1) 18 ended in the hand moving away from the object and 15 toward the object, if anything, a difference in the direction opposite to that predicted by the recalibration hypothesis. Therefore, even on a less strict criterion we have no evidence for amodal guide usage in these adult subjects.

If we look next at the number of contacts with the object in relation to the total number of arm extensions in Condition C, we see first of all the very poor performance of the 'low information group'. On collapsing the groupings we still see a very poor ratio of arm extensions ending in contact (45 per cent) in relation to the other conditions (A = 100 per cent; B = 60 per cent). It could be argued though that this percentage is good, considering the artificial signal being produced by the guide (artificial in the sense that such a signal has never previously been experienced). This argument breaks down, however, when we look more closely at what makes up this percentage figure. Those subjects who did contact the object did so after a series of wide-ranging gropings, having been prompted by the experimenter and/or by their experience in the previous conditions that there was something to be found within reach. (Only one of the subjects who performed Condition C first succeeded in contacting the object. This subject was in the 'high' information group.) Once the object had been touched they would occasionally lean forward and touch it with their head. (Five subjects touched it with their ear.) Thereafter they would reach to the same position as before. If the object's position was changed (after three successes) they would typically reach to the previously successful position, despite the object having moved slowly to the new position and this change of position having been signalled by the guide. No radial tracking or spontaneous head movements were observed with any of the subjects. We can only conclude that the 45 per cent figure for reaches ending in contacts is very poor and, if anything, overestimates the true success rate in this group.

It is possible that, despite the search task proving extremely difficult under sonicguide conditions, subjects might have shown some improvement in performance in tasks involving manipulation. This was not the case. Results of the manipulation/stacking task are presented in Table 4.2.

Table 4.2: Mean time taken for sighted adults to perform stacking task under three conditions: A - Light B - Blindfolded C - Blindfolded with guide

Time Taken	Condition		
	A	B	C
$\bar{x}$	3.8 sec	8.9	9.9
SD	0.4 sec	1.7	2.4

A correlated t-test showed that Condition B was significantly more difficult than Condition A, as expected ($p < .05$; df = 17). Condition C was slightly more difficult than Condition B, although this was not siginificant. Clearly the guide was of no help in the stacking task, possibly acting instead as a slight distraction.

DISCUSSION:

The results obtained provide no evidence for the possibility of intersensory substitution in adults. The overriding factor determining performance in the search task was not the amount of prior information given to subjects but the modality of presentation of the task. Despite the sonic-guide presenting information consistent with that produced by audible objects plus the additional information of size, shape and so on, the wearing of the guide seemed, if anything, to depress performance. The additional information seemed only to overload the sensorily specific use of information presented in the auditory modality.

Like the older blind subjects of Chapter 2, the sighted subjects seemed to find the additional information confusing. This suggests that they had already worked out a set of sensori-motor responses which were specific to audition, touch and vision respectively. The auditory information presented by the sonicguide, although conforming to the abstract amodal properties of visual information - in terms of size, distance, direction, texture and change in these higher-order properties - did not conform to the sensorily specific qualities of auditory information. For instance, bringing an object to the ear, instead of increasing the sound, would result in the loss of the sound as the object would then be out of the field of the guide. Responses which were formerly appropriate to noise-making objects were no longer valid. Sound could no longer be used by these subjects to provide information about objects and events, but had become a property of objects themselves. Even the most abstract quality of the guide, which would be that the signal presented information about events in space, was not made sense of. It was only after the 'low information group' had been told of this property that they were able to do anything other than freeze.

If, then, there is no evidence for perceptual pick-up of the information supplied by the guide, is there any evidence for its use as an operant signalling device, as was suggested by some of the results obtained with the older blind children discussed in Chapter 2? It will be recalled that once those adult subjects who did demonstrate reaching with the guide succeeded in contacting the object, they were then able to reach and grasp the object again if it remained in the same position. Any change in position was not compensated for. It seemed, however, that this was performed simply by a re-enactment of the motor response. As long as the first contact had been made, the same response could be observed even if no sound was coming from the guide, i.e. when the object was out of its field. This interpretation was supported by the observation that even the first contact made was often made when the object was out of the field of the guide. In such cases, there could be no possible use of the guide signal, even as an operant signaller. That is not to say that it could not be used operantly given a longer time for practice in its use. Indeed the blind adults using it as a mobility device would testify to this. In the time available, though, there was little evidence of its use in this way. The only subjects who appeared to demonstrate operant use belonged to the 'high information group' who reported that they went through a process of matching each component of the signal. They would, for example, reach out and on contact with the object (after groping) would try to associate the location of the object in relation to themselves by holding on to the object and making head/body movements.

During testing of subjects, an attempt was made to determine what type of information given verbally to the subjects was most useful, given that the 'low information group' had to be given some degree of information before they would do anything with the guide. It was found that the most useful information appeared to be that the signals of the guide conformed in some way to distance, and so on, without actually stating the nature of that relationship. Next in importance was the information that head movements would be useful. Both of these instructions are fairly abstract. Overriding them was the necessity of practice in using the two instructions to determine, for themselves, the more specific aspects of the signal, e.g. associating distance with pitch; discovering that head movements could indicate distance and direction. These observations would support the idea that an extended intensive training period would be necessary for operant use of the guide by adult subjects.

In summary, it would seem that we must look at a younger sample of subjects if we hope to obtain evidence of amodal usage of the guide as a perceptual surrogate.

B. Sighted School-Age Children

INTRODUCTION:

Although the results obtained with adult subjects in the previous section suggest that intersensory differentiation has by that age already occurred, it was still thought possible that younger children might be able to use the guide amodally. It was seen in Chapter 2 that blind children of about 8 years of age were able to make some sense of the signals produced by the guide, albeit that this use was restricted to obstacle sensing. It may be that the reason blind children do not demonstrate amodal usage is because of other problems associated with blindness. These problems may be of the more "affective" or emotional type, making it difficult for them to cope with a novel auditory input and leading simply to freezing in this new situation.

It could also be the case that perceptual pick-up of the information is present but that the set of sensori-motor responses they have developed to cope with auditory information cannot demonstrate amodal pick-up. An example may illustrate this point. The blind children tested showed no use of the radial direction index of the guide; no radial tracking of objects was observed. It could be that this is simply due to lack of practice in having to centre auditorily-defined objects with head movements. It could then be that radial information is being picked up amodally but that the response necessary to utilise this information is not available. With sighted children, a centering response is clearly present in the visual modality; radially directed reaching and tracking is precise in school-age children. The question is whether these sighted children use the amodal properties of such information or whether it is sensorily-specific. If amodal information is being used then we would also expect tracking and/or reaching to sonically specified objects,

One possible reason why two of the blind children were able to demonstrate some success in using the guide as an obstacle detector could have been that their teacher had given them this information prior to the tester's visit. It was therefore felt that by studying responses to the sonicguide in naive sighted subjects, some clearer insight would be obtained as to whether intersensory substitution is still present in early childhood. If so, we would expect perceptual or amodal guide usage to be manifested, with the subjects using the signals provided by the guide in a manner equivalent to the use of vision. The responses studies were reaching, tracking and a manipulation task.

METHODOLOGY:

Subjects: The subjects all attended a local state primary school. They were selected by their class teachers as representing a spectrum of intelligence and abilities. Their ages ranged from 5 years 4 months to 6 years 2 months with a mean age of 5 years 8 months. Six subjects were selected, three boys and three girls. Parents had been instructed, when asked for permission, only to inform their children that they were going to be helping blind boys and girls. No other information was given to the subjects before the experiment.

Design: Due to transportation problems involved in visiting the school, it proved impossible to run the condition involving presentation of a sound-making object. Two conditions were therefore presented to each subject. Order of conditions was random.

Condition A involved presentation of a visually defined object. Responses to this object served as a baseline measurement for success of reach, which hand was used, latency of reach and so on.

Condition B involved presentation of the same object, this time specified sonically by the guide, with the subjects blindfolded. The object used in both conditions was a large-size Varooshka doll measuring 20 cm high x 10 cm at its widest point (this was the same object as was used with the sample of older blind children in Chapter 2). In addition a manipulation/stacking task was presented to each child using the same doll. This task was the same as that presented to the blind school-children in Chapter 2, involving the location and insertion of the smaller doll inside the larger doll. For this task, three sub-conditions were run:- (1) with the object visually specified (i.e. without the guide), (2) with the object sonically specified (blindfold), and (3) with the object tactually specified (blindfold without the guide). Order of presentation of conditions was randomised.

Procedure: For the guide condition, the testing was formulated into a game of "blind-man's buff". It was realised that in the guide condition, this would give the child the benefit of knowing beforehand that he was perhaps expected to find something and could in itself generate search patterns. This could only work in the direction of the subject being more likely to find the sonically specified object than when not given any other verbal information. It was felt, however, that this information was necessary for experimenter/subject rapport. Subjects were seated on a standard school chair, and in Condition B blindfolded and the guide switched on. In Condition B, it was ensured that no other objects were within the range of the guide. The standard question of, "Can you tell me what is happening?" was then asked. After this 25 approaches and withdrawals of the object were presented in the midline. None of these ended in contact with the subject. After this, 25 approaches and withdrawals of the object ending in tapping the subject's nose were carried out. If the subject had not reached or grasped the object by the tenth of these second set of trials, he/she was told to try and catch the object. Thereafter, if he did not reach spontaneously, he was told to attempt to catch the object before it tapped him on the face. The object was then moved from left to right and back for 15 trials. Subjects were not informed that the movement was now radially directed, but simply requested to catch the object as before. Reaching to a visible object consisted of a 30 second presentation of the object in three positions: midline, 30° to left, 30° to right. The stacking task was carried out with subjects seated at a table. Behaviour was video-recorded for later analysis.

<u>RESULTS</u>:

The results of the search task under the two conditions are presented in summary form in Table 4.3.

<u>Table 4.3: Success/failure of sighted school-children in the search task under two conditions: a) search for a visually specified object; b) search for a sonicguide specified object</u>

SUBJECT	CONDITION							
	VISUAL (A)			SONICGUIDE (B)				
	Mid.	30° L	30° R	Midline			Radial Reach	Radial Track
				No object contact	With object contact			
1	✓	✓	✓	-	-	2	-	-
2	✓	✓	✓	-	-	3	-	-
3	✓	✓	✓	-	-	4	-	-
4	✓	✓	✓	-	-	1	-	-
5	✓	✓	✓	-	-	-	-	-
6	✓	✓	✓	-	-	-	-	-
				Trials 1-25	Trials 1-10	Trials 11-25		

In the series of approaches/withdrawals ending in contact after midline presentation, the first ten trials were seen as an index of possible operant use. Over the ten trials it was expected that, if the guide could be used as an operant signalling device, subjects would reach for and contact the object. Neither contact nor reaching was observed in this phase. Subjects were therefore told that the object was coming to them and that they should attempt to catch it before it touched them. As can be seen, in this series of 15 presentations in the midline an average of under two successful grasps was seen, with one child scoring four. However, even this seeming success rate is, on closer analysis, a poor achievement. In all of these "successful" grasps the subjects first held both hands at the midline at chest height. Grasping only occurred after the object had touched their fingers, i.e. grasping was only tactually elicited. None of the qualities of the sonicguide was being used. Also no radial reaching or tracking was obtained, nor were any spontaneous head movements observed.

The results of the manipulation/stacking task can be seen in Table 4.4.

The results show that the task was performed poorest in the guide condition. It seemed that the signal provided by the guide acted only as a distraction, thereby inhibiting performance.

Table 4.4: Results of manipulation/stacking task for sighted children under three conditions of presentation

Subject	CONDITION		
	Light	Blindfold - no guide	Blindfold with guide
1	5 sec	35 sec	75 sec
2	5	5	7
3	3	8	12
4*	-	-	-
5	5	7	8
6	4	20	20
$\bar{x}$	4.4	15	24.4

* This subject was distressed at being blindfolded. She therefore did not participate in this task.

DISCUSSION:

The results provide no evidence for the hypothesis that the sonicguide can be used as a perceptual surrogate with children of this age. Use of the amodal information in the guide signal appears to be absent. The possibility of its use as an operant signalling device, as seen in some of the blind sample in Chapter 2, also appears to have gone unrecognised. The only way in which these subjects would grasp the object was after supply of tactile information. The additional information of the guide proved not to be an aid to performance; on the contrary, it seemed that this additional information was an overload. In addition, despite having had experience of controlling input of information with vision - using head/eye movements for instance - the sighted subjects showed no transfer of the use of this control with the sonicguide. No radially directed tracking or reaching was observed, no object fixation was seen, nor was there any evidence of spontaneous head movements. Even the most abstract qualities of the signals presented by the sonicguide, namely the information that there is something "out there", did not appear to be picked up. This can be seen if we recall that the order of conditions was random. It might have been expected that those subjects who received the visually defined object condition first, and reached for the visible object, would have exhibited some small degree of transfer to the second, sonicguide condition. If so, we would have expected at least searching by head/eye or hand movements for the object which had previously been in the visual field. No such transfer occurred, however, which would suggest that not even the most abstract properties of "out there" information was being picked up by this group of subjects.

If intersensory substitutability does exist, therefore, it would seem that we have to look at a sample of children who are younger than 5 years of age. It would appear that by this age, sensory specification has already occurred.

C. Sighted Pre-School Children

INTRODUCTION:

The results obtained with sighted adults and school-age children suggest that we must look at younger subjects if we are to obtain evidence for guide use as a perceptual surrogate. A younger subject pool of pre-school age children was therefore investigated. It was necessary that the demand characteristics of the tasks given to the previous samples were formally equivalent with the characteristics of the tasks presented to the pre-schoolers. A reversion to the tasks given to the adult sample was therefore adopted with a manipulation/stacking task being incorporated. Three differences existed between the search tasks used here and those given to the school-age children. These differences were: (a) the soft toy - a small duck - was used as the object; (b) the condition with an auditorily-defined object was used, as with the sighted adults; (c) the object was stationary at each of three fixed positions, i.e. the object was not moved to and from the child in the midline.

METHODOLOGY:

Subjects: Six subjects (three male, three female) were selected from the Psychology Department Nursery. All of the children in the sample were used to acting as subjects in other experiments and were eager to participate in the study. Ages in the study ranged from 3 years 1 month to 4 years 2 months with a mean age of 3 years 8 months. No information had been given to the subjects prior to the experimenter's arrival.

Apparatus: The apparatus for this experiment was the same as that for the experiment involving adults (see pp. 143-144).

Design: The experiment again involved a search task with three conditions.

Condition A involved presentation of a visible object - the fluffy duck mounted on the end of a boom.

Condition B involved presentation of the duck when auditorily specified.

Condition C involved presentation of the duck when specified by the guide.

For the latter two conditions, subjects were blindfolded. Order of conditions was randomised for each subject. For Condition A the object was presented for 30 seconds. Condition B lasted 3 minutes as did Condition C. For all conditions, the object was presented just within reach of the child in each of three positions - midline, 30° left, 30° right. All positions provided the same signal for the height of the object. The middle of the object was in line with the subject's forehead. The object was then slowly moved left to right and back ten times in order to observe radially directed tracking or reaching. For this the object was 20 cm. from the child's head.

A manipulation/stacking task using three platforms was then carried out. The platforms were 200 x 200 x 50 mm., 100 x 100 x 50 mm. and 50 x 50 x 50 mm. The subject was asked to put the small one on top of the next smallest and then both on top of the biggest. Again three conditions were run - light, blindfolded without guide, blindfolded with guide.

<u>Procedure</u>: Subjects were taken individually to the test area, the same room as was used with the adult subjects. The subjects were already familiar with the room. For the two conditions in which they were blindfolded, they were informed that they would be playing a game in which they had to find toys without being able to see them. It was felt that it was necessary to provide this information so that the children would not find the experimental situation distressing. Subjects were seated on a standard school chair and, in Conditions B and C of the search task, blindfolded. For the base-line Condition A, position of presentation was random with each position being presented only once. Position was changed after one successful reach (success being a reach ending in contact). For Conditions B and C,, position was again randomly assigned and changed after three successful reaches. If no reaches were seen in any of the conditions, subjects were told to try to catch the object. The manipulation/stacking task was again carried out while subjects were seated at a table.

RESULTS:

Results of the search task under the three conditions are presented in Table 4.5.

Table 4.5: Results of search task presented to pre-school children

SUBJECT	CONDITION								
	A			B			C		
	Reaches			Reaches			Reaches		
	30^oL	Mid	30^oR	30^oL	Mid	30^oR	30^oL	Mid	30^oR
1	✓	✓	✓	-	✓	-	-	✓	-
2	✓	✓	✓	✓	-	✓	-	-	-
3	✓	✓	✓	-	✓	✓	-	-	-
4	✓	✓	✓	✓	-	-	-	✓	-
5	✓	✓	✓	✓	✓	✓	-	-	-
6	✓	✓	✓	✓	✓	-	-	-	-

As with the adults and school children, reaching to a visible object was accurate to all three positions. Latency to reach was on average 1 second. In the second condition, presentation of an audible object, we see that reaching did not occur with all subjects to all positions. The average latency in this case was 35 seconds. The quantitative aspects of this reaching in this condition were therefore poorer than those for the visible object, as is to be expected. If we look at the results for Condition C, we again see a marked deterioration in reaching. The latency to first reach for the two subjects who did actually reach for the object was 1 m. 50 sec. and 2 m. 15 sec. After contacting the object, both children held it for several seconds, without making any exploratory head movements with the guide. After the third successful contact, when position was changed, no further contacts were observed. In fact, despite the information supplied by the guide telling them that the object had moved, both children reached to the midline position, the position which had previously been successful. Moreover, in the two cases where reaching success was demonstrated, the midline was the first presentation. No reaches were observed in any subject when the object was presented off the midline. No subject showed any evidence of lateral head movements or other index of use of radial direction information. All subjects simply sat with their heads still, seemingly very puzzled by the sound.

It is interesting, nevertheless, to look more closely at those two cases where there was successful contact with the object. In both instances, the subjects had to be told to try to catch the duck before reaching occurred. In both cases, the guide condition was last to be run, the two subjects having first had experience of Conditions A and B. With both subjects, the reach consisted of both hands being brought to the midline, palms extended outwards, and then a sweeping from the side and back to the middle until tactile contact was made. No accompanying head movements were observed. On contact, object exploration was tactual with no evidence of use of the guide for edge detection or use of any of the other signals it presented.

Table 4.6 shows the time taken to stack the three blocks used in the manipulation/stacking task.

Table 4.6: Results of manipulation/stacking task with sighted pre-school children

SUBJECT	CONDITION		
	Light	Blindfolded - no guide	Blindfolded - with guide
1	15	100	125
2	8	50	54
3	20	100	180
4	24	29	180
5	35	180	180
6	18	26	145
$\bar{x}$	20	81	144

As can be seen the guide showed no improvement over tactile cues alone, in fact proving to be a detriment to performance. The maximum time permitted of 3 minutes elapsed without success for three subjects in the guide condition (Condition C). With two of these subjects, this was the first of the three conditions presented. With the third subject (S5), Condition C was run after Condition B: for both conditions this subject exceeded the maximum time permitted. That he was able to understand the task is seen from the result of the last condition presented to him, the visible object.

DISCUSSION:

For this group of subjects, we again have no evidence for the guide being used as a perceptual surrogate. In the stacking task there is again evidence of it proving to be a distraction when the child is attempting to concentrate on what is for him a difficult task, difficult because such tasks are normally carried out using vision. In the search task we have no evidence of pick-up of the radial direction of an object. No spontaneous reaching was seen at all. It seemed that for this group of subjects, the sound from the guide was simply something to be listened to. It provided no information for them which had any meaning. Although not being used in the perceptual or amodal sense then, it was possible that the guide was being used as an operant signalling device. This in itself would be more use than was evidenced with the older school-age children.

This hypothesis appears to be plausible from the evidence of the subjects who demonstrated repeated successful reaching to the object in the midline. The reason they did not transfer when the object was moved to a different position could be, on an operant hypothesis, that they had not had sufficient time to learn the meaning of this new signal. However, this hypothesis also can be discounted if we recall the more detailed analysis of the reaching to the midline of these subjects. This reaching only occurred <u>after</u> being told to catch the duck and <u>after</u> the other conditions had been run. Furthermore, the type of reach was nothing like that obtained under visual conditions, being describable more as groping, awaiting tactile confirmation and making no use of the guide. Nevertheless comparison of these results with the performance of the school-age children shows that performance of these pre-schoolers is slightly better. It could be that the "out there" quality of the signal may still be being picked up with the younger children. It seems more likely, however, that with these subjects, there was some degree of transfer from the other conditions to the sonicguide condition. That it was a small degree of transfer can be seen by the lack of any exploratory head movements to confirm the meaning of the information about "out there". There seemed to be no use at all being made of the control aspects of the guide. Instead, sounds for this age group too are merely events to be listened to and are thus modality specific. It would again appear that evidence for amodal pick-up information, if it exists, must be sought from yet younger subjects.

D. Sighted Infants

INTRODUCTION:

The results obtained with the previous groups of subjects would suggest to some that there is little point in attempting to look at subjects who are any younger. Most non-psychologists would argue that if we cannot demonstrate a particular response, skill or ability with adults then we would certainly not be able to demonstrate it with infants. Indeed, many academic psychologists would make the same point. Prazdny (1980), for instance, in an attempt to simulate by computer the development of the object concept, stated that, if the computer programmer cannot simulate the behaviour, then there is no possibility of the infant being capable of demonstrating the behaviour. Nevertheless, the data base of previous work presented in Chapter 1, plus the results obtained with blind infants, would suggest that it may be possible to demonstrate superior guide use with infants, a finding which would be in accordance with a differentiation theory of development.

The use of a search task seemed an appropriate tool of investigation. As was mentioned in the introduction to this study, the possibility of obtaining reaching as a measure of search under guide conditions was loaded against any such demonstration with infant subjects. Therefore any results pointing to use of the guide could be considered as strong evidence in support of a differentiation theory. This means that it is crucial that we are aware beforehand of what we would consider as being "equivalent" reaching responses in the light and in the other conditions. More than with the previous groups, we must define what we would expect our reaching responses to be with infant subjects. In order to do so, it is necessary that we firstly make a brief digression into previous infant work on the development of reaching to visible objects, a field which is by no means devoid of controversy, with some workers reporting evidence of reaching in young infants, other reporting that there is no such evidence.

The classic position on the development of reaching is that put forward by Piaget (1953) in which co-ordination between vision and prehension is seen as a gradual development occurring over the first few months of life. White, Castle and Held (1964) regard the motor activity of the neonate as simply random thrashing of the limbs. Trevarthen (1974, 1975) has also taken this stance, describing the components of mature reaching - arm extension and hand closure - as non-functional in the neonate. Ruff and Halton (1978) report that the arm extensions of the neonate are not directed, and point to the fact that, in their experiment, the same numbers of arm extensions were seen in the absence of an object as in its presence. Field (1977) and DiFranco, Muir and Dodwell (1978) claim to have shown that while the components of reaching can be observed in neonates, they appear in an unco-ordinated form.

Other researchers claim, equally strongly, to have demonstrated the presence of true reaching ability in neonates. The work done by Bower, Broughton and Moore (1970 a, c) was the first systematic study to show the intentionality of the neonate's reaching. McDonnell (1979), using a signal detection analysis, showed that arm movements changed when stimulus position was changed. In a further study (McDonnell, Anderson and Abraham, 1979), results suggested that movement and orientation occurred more frequently for the left hand, a finding which was taken as demonstrating early evidence for right-hemispheric functioning in visuo-spatial abilities. Bower (1974; 1979 a) makes a distinction between neonatal and older infant reaching, although arguing that both are present and functional. The neonatal reaching, which he describes as Phase I, is characterised by reaching in which both the reach and grasp components are visually elicited; hand closure begins without tactual input. Success in contact is around 40 per cent at this stage. This early reaching behaviour drops out of the infant's repertory, reappearing in similar form at about 16 to 20 weeks; thereafter it is replaced by the more successful Phase II type of reach, with its much improved success rate. Phase II reaching is characterised by visual guidance of the hand, with the hand pausing at the object before grasping; the two components of reaching - arm transport and hand closure - are separated by about 450 msec. on average (Bower, 1979 a). De Schonen (1980) has also found that neonates of 3 to 6 days of age can demonstrate reaching, with a significant left arm preference. A control condition was carried out in this study, with no object present in the field. It was found that, contrary to the study of Ruff and Halton (1978), reaching and arm movements decreased in this condition, with reaching only being oriented when the stimulus was present.

It would appear that the difference in results of those who deny the existence of neonate reaching versus those who argue for its existence lies in methodological and procedural differences. Ruff and Halton (1978) presented a stimulus to their subjects for only one and a half minutes. It is quite conceivable that it may take longer than this for the neonate to organise a reaching response. This is especially the case, if, as with most neonates, the behaviour is never practised. The results of Bower, Broughton and Moore (1970 a) were obtained with a 3 minute presentation of the stimulus. This would suggest that a study of neonate reaching must incorporate into its design sufficient time for the organisation of the response.

Clearly then, the results of the present study will have some relevance to the debate on the existence or non-existence of neonate reaching, at the very least in the visible stimulus condition. In addition, the nature of the development of reaching from the neonate period onwards is, as yet, a matter of some controversy. Arguments to account for the development of reaching on the basis of either maturational or environmental factors have been espoused. A study by Bower (1977 e) suggested that environmental factors were mainly responsible for the transition from Phase I to Phase II reaching. In that study, a group of infants were given daily practice in reaching to a dangling object from the age of one week. Given this practice, the infants continued to reach up to 20 weeks of age. This would seem to suggest that the reason for the usual drop-out of Phase I reaching is due to lack of environmental input, there being no opportunity for reaching. However, it was seen that between about 4 and 16 weeks the second component of reaching - hand closure - dropped out. The infants were able to reach for an object without automatically closing their hands on approach. Grasping resumed at around 17 weeks and was characteristic of the Phase II type, a reach-then-grasp rather than a reach-and-grasp. A maturationist might hypothesise from this that the drop-out and re-emergence of grasping must be maturationally determined. This is not, however, the only possible answer. It will be recalled that the stimulus used was a dangling object. The chances of success in grasping this object were low with a Phase I reach. It is quite possible that it was due to this lack of success, an environmental explanation, that grasping dropped out.

White and Held (1966) also found transition at 14 to 16 weeks from visually elicited grasping to tactually elicited grasping. Bruner and May (1972) described the same transition at an age of 26 weeks. Bruner and Koslowski (1972) also found that 20 week old infants will demonstrate tactual elicitation of grasping when the hand is under visual guidance to the object. It would appear from this that there must be some maturational influence on the development of reaching. The infants studied by White and Held (1966) were given a stationary object to reach for. It was found that, despite the high success rate of Phase I reaching, the Phase II pattern of reach-then-grasp did emerge.

Bower (1979a) has pointed out the facilitative effect of hand regard at around the age of 12 weeks on the emergence of Phase II reaching, and that hand regard itself appears to be maturationally determined (Bower, 1974 b). It would appear that the emergence of Phase II reaching is maturationally determined, but that it is facilitated by hand regard. The interrelationship of maturational and environmental factors is at present unclear, mainly because we do not know (and have no control over) what is happening outside of the reaching experiment. We do not know whether responses which we accept as being maturationally determined are in fact environmentally determined, with the necessary environmental input, as yet, undefined. One means of determining the relative influence of maturation and environment would be to present a novel sensory input - like the Sonicguide. Any results obtained with reaching under guide conditions will therefore also go some way to resolving the debate over the nature of the development of reaching.

If we hope to achieve any of the above, it is essential that we have a detailed analysis of the reaching responses in all the three conditions, visible object, object specified by sound alone, and object specified by the guide alone. We must look at one-handed versus two-handed reaching, latencies, frequencies, whether the reach ends in a grasp and so on. With this sort of analysis, we will hopefully be able to examine not only the nature and limitations of intersensory substitution in infancy, but also obtain evidence relevant to reaching, auditory-manual co-ordination, control of stimulus input and auditory localisation in infancy.

METHODOLOGY:

Subjects: Subjects were sampled from a pool of infants whose parents were willing for them to participate in research studies. 45 neonates were observed as well as 6 infants at each month from 1 month up to 12 months. As far as was possible, sex of subjects was counterbalanced within the age groups. The mean age and age ranges of the sample are provided in Table 4.7.

Table 4.7: Age and sex of subjects in sighted infant cross-sectional study

AGE GROUP	NO. OF SUBJECTS			AGE RANGE	MEAN AGE
	Male	Female	Total		
Neonate	23	22	45	7-29 days	20 days
2 mnths	3	3	6	6.0-9.3 wk*	7.2 wks
3	2	4	6	10.0-12.5	11.5
4	3	3	6	15.0-17.4	16.0
5	3	3	6	18.5-22.5	20.4
6	3	3	6	22.6-27.2	25.4
7	3	3	6	27.0-30.5	28.1
8	3	3	6	30.1-32.3	31.6
9	2	2	4	34.6-37.6	36.6
10	2	2	4	38.6-41.6	40.1
11	2	2	4	42.4-46.6	43.5
12	2	2	4	52.6-54.6	54.2

* 9.3 denotes 9 weeks 3 days etc.

Apparatus: The stimulus object, V.T.R. equipment and tape recorder used are described in Section A. It was felt that to introduce a blindfold with the infants would be over-intrusive on the co-operation of the parents. Instead, testing of the infants was done in the dark. As it was, to many of the infants' mothers even the wearing of the sonic-guide seemed cumbersome. An infra-red light source of 100W power was used. Two polaroid filters covered the light source which was "bounced off" the ceiling to "illuminate" the field for the infra-red sensitive camera which was used. The experiment was carried out in a light-tight room measuring 4 m x 4 m x 3.5 m. As a result, no possibility of using vision in the two dark conditions existed. Neonates and infants between 2 and 4 months of age were laid on their backs on a mattress 1.5 m x 0.75 m. Supports were provided for their head and for both arms. Without such support, neonate reaching cannot occur (Bower, 1979 a). Older infants (4 to 7 months) were strapped in a standard infant chair reclining at 30° with their arms and hands free to move. With infants older than 7 months of age, it was found that they cried in all conditions as soon as the lights were extinguished. In an attempt to circumvent this problem, presumably a result of fear of the strange, these infants performed the experiment while sitting on their mother's lap.

Design: Only the search task was carried out in this study, since stacking tasks were clearly inappropriate. The three

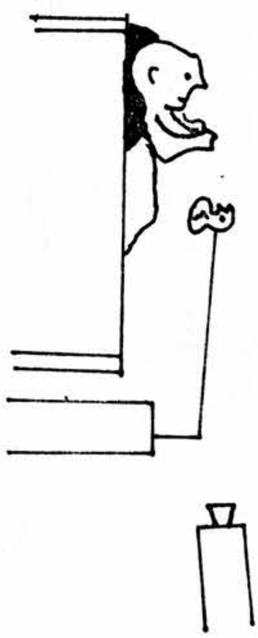


Figure 4 Diagram of camera position for neonate reaching

conditions, A, B and C, used in the adult and pre-school group were run. Order of presentation of conditions was randomised for each subject. Due to the strong possibility that the reason some workers obtained no neonate reaching was due to the lack of sufficient time for stimulus presentation, the stimulus was presented for 6 minutes in each condition. If a reach occurred within this period, a time of 3 minutes was taken from this point. The position of the object was fixed for each condition at either 30° left of midline or 30° right of midline. Positions were selected off the midline because of the problems neonates have in maintaining posture in the midline. Position was changed between conditions so that the object was never presented consecutively in the same location. For example, if the order of conditions was B, A, C, the order of presentation might be Right, Left, Right.

Procedure: Subjects were placed in the appropriate seating and the experiment was not commenced until it was clear that the infant was both awake and not in distress. For conditions B and C, the lights were extinguished and, for all conditions, the boom supporting the object was then swung in. The object was set for each subject at a distance equivalent to his/her full arm extension. For Condition A, Experimenter I commenced timing of 3 minutes when either hand was extended to the height of the object (see Measurement sub-section for rationale behind choice of this measure as a criterion of reaching). In conditions B and C, a second experimenter, E2, was positioned outside the room and observed a remote T.V. which monitored the infant's behaviour. After the room lights were extinguished, E1 moved the object into position; exact position of the object was called to E1 by E2, who then began timing as in condition A. To facilitate identification from the monitor of the point when the infant's arm was extended to the height of the object, a cursor was attached to the screen in line horizontally with the base of the stimulus. If no reaches were observed within 6 minutes, the trial was terminated and the next condition commenced. If the infant was distressed, the experiment was stopped and only re-started once the infant was placated. If this involved the use of a pacifier this was removed during presentations. Timing was continued after the infant again demonstrated a reach to object height. If the condition had to be re-started more than twice because of distress, that condition was terminated and the next one commenced.

The tape recorder (condition B) or sonicguide (condition C), was only switched on once E2 had reported that the object was in position. If there was any interruption of presentation the guide or tape recorder was switched off. There was therefore no possibility of the infant associating the object's position as indexed by vision with the auditory information presented in conditions Baand C. During stoppages and between conditions, the object was swung out of sight of the infant. Lastly, because of the length of time necessary to carry out the experiment, many subjects did not complete the experiment in one session. In those instances, mothers were requested to bring their infants back within three days. If, after the second visit, the experiment had still not been completed, the mothers were requested to make a third visit. If the experiment was not completed after this visit, the experiment was considered terminated for that subject.

Measurements: The crux of any experiment investigating reaching in infants, particularly in neonates, is to distinguish what constitutes a reach as opposed to random arm movements. Bruner and Koslowski (1972) observed that any choice of categories will essentially be arbitrary. The criterion adopted here for the onset of timing each session, an arm extension to the height of the object, may at first appear to be lax. However, if we compare arm extensions to the sector where the object is located with arm extensions to the opposite sector, this is in fact a fairly strict criterion. If the movements were random then we would expect equal numbers of arm extensions to each sector. We would also expect that any arm movements before the reach occurred (to object height) would be random. To test this, a line was drawn horizontally at a point which bisected the distance between the infant's shoulder and the base of the object. Numbers of arm extensions to this height for object sector and opposite sector were then computed. If true reaching was occurring, we would expect to see equivalent extensions to this mid-height for either sector, but we would expect to see a significantly greater number of arm extensions to object height to occur in the sector containing the object. It is also possible that for true reaching, we would see a greater number of both mid-height and full extensions to the sector containing the object than to the other sector. This suggestion derives from the possibility that it may take longer for a neonate to organise a reaching response.

Quantitative measures looked at included latency, frequency and duration of reaches, number of contacts and whether the contacts were grasps or swipes. Reaching was also divided into either reach-and-grasp or the directed reach-then-grasp type. Other measures taken were whether the infant was fixating the object while reaching and whether there was any effect of side of presentation of the stimulus.

RESULTS:

Before analysing for comparisons across age groups within this infant group, the data collected from neonates will be looked at in more detail, as this group contained the largest number of subjects. In addition, it was hoped that this age group might provide some data of relevance to the controversy over neonate reaching discussed above.

NEONATES

Out of the 45 neonate subjects in the original sample, 15 subjects either did not complete all three conditions, or else did not reach in any of the conditions presented. The results of those subjects who did not complete all three conditions were examined to discover if there was any one particular condition which seemed to be associated with their unwillingness to participate in the study. If so, it might then be hypothesised that that condition, as it was most upsetting, was least "natural". It was found that 5 infants would not sit through Condition A, 8 through Condition B, and 7 through Condition C (some infants found more than one condition upsetting). These results show no significant differences among conditions. These results were then examined for an order effect, it being hypothesised that in the initial visit the subjects might not have sat through a particular condition simply because it was last to be run and they were by then fatigued. A Friedman two-way analysis of variance (Siegel, 1956) was performed on order of presentation X condition. There was found to be a slight order effect, significant at the $p < 0.2$ level with most distress occurring in the last condition to be run. This suggests that the main reason why these neonates dropped out of the sample was that they were indeed fatigued by the length of the experiment. Failure to complete the experiment on the two subsequent visits could have been due to a number of reasons; perhaps the mothers were over-anxious for their infant to perform, or perhaps the infant had associated the experiment with being distressed.

To investigate the possibility of random activity (see

above), results were analysed to compare <u>mid-height</u> extensions to the correct sector (i.e. the sector with the object) versus extensions to the other sector, <u>prior to</u> the first extension to the height of the object. A t-test was carried out for each condition comparing correct versus incorrect responses. Results were as follows:
<u>Condition A</u>: $p < 0.25$; <u>Condition B:</u> $p < 0.5$; <u>Condition C</u>: $p < 0.3$. The results were all non-significant, although indicating a slight trend toward arm extension to the mid-point being directed to the correct sector. If we were to take mid-point activity as our criterion of reaching, then it would appear that arm activity is essentially random.

Reaching frequency, this time taking a reach as being an arm extension to the <u>height of the object</u>, was then computed and latency to first reach compared across conditions. A repeated measures Analysis of Variance[1] carried out on both of these results. Latency to first reach showed that there was an effect of condition, with first reach in Condition A taking slightly longer than in Condition C, which in turn took slightly longer than in Condition B. This result was significant at $p < 0.02$. This pattern of results could be accounted for by the fact that, with the passive sound source, (Condition B) no other stimulus was present, while in the light condition (Condition A), although the experimental room provided minimal other stimuli, there were still shadows from

---

[1] I gratefully acknowledge the assistance of Rodney S. Noble for advice on this analysis.

overhead lights and other items in the room which might have distracted the infant from the stimulus object.

The analysis of variance on reaching frequencies showed that there was no significant difference across conditions ($p < 0.69$). This is in accord with a differentiation theory which would predict that the modality of presentation of the information is irrelevant. Next, the number of reaches to the appropriate sector, i.e. the sector containing the object, was compared with number of reaches to the opposite sector (with reaches to the midline being included in the latter). A highly significant difference was obtained ($p < 0.0001$) with reaches being significantly in the direction of the appropriate sector. The reaching observed was therefore directional, as compared with the mid-height arm extensions discussed above.

Effect of side of the stimulus on reaching frequency was then computed. No side effect was obtained ($p < 0.9$), a finding which contradicts the results of McDonnell et al (1979) and de Schonen (1980), both of whom found a preference for reaching to an object on the left. Two-way interactions of Condition X Side of Presentation, Condition X Appropriateness of Sector and Side X Appropriateness were all non-significant ($p < 0.85$; $p < 0.74$; $p < 0.83$ respectively). Likewise a three-way interaction of Condition X Side X Appropriateness was non-significant. No hand preference was seen across conditions: Left hand: $p < 0.67$; Right hand: $p < 0.68$. This again contradicts work by McDonnell et al (1979) and de Schonen (1980) who found asymmetry in reaching with a left-hand preference.

It may be argued that, although there was evidence of appropriately directed reaching in Condition C, this may not necessarily index any use of the guide on a perceptual or amodal basis. In fact it may not even index use of the guide on an operant basis. It is conceivable instead that the neonates, on extending their arms, swept across and accidentally contacted the object. Subsequently, the frequency of their reaching increased to that sector because that was the area of contact. This in itself seems implausible, as Wishart, Bower and Dunkeld (1978) have shown that neonates do not have the awareness of body schema necessary to make use of such accidental contacts. It is not necessary, however, to posit this type of argument if we take into consideration the higher-order information supplied by the guide. One of the higher order properties signalled by the guide is direction, with straight-ahead and right versus left invariant. Making this assumption, we can then make the following argument concerning first reaches, i.e. the first arm extension to the height of the object: if the infants are using the invariant property of direction, we would expect a greater number of first reaches to the sector in which the object is located than to the other sector. Appropriateness/inappropriateness of sector of first reaches was therefore totalled and, as is seen from Table 4.8, the results for all conditions were highly significant. This shows that, not only for the guide condition, but for all conditions, the reaching of the neonates was not random but directional. In Condition C, it would appear that the infants must have been utilising the amodal property of direction. Since all reaches considered in this analysis were first reaches, we can discount use on an operant basis.

Table 4.8: Number of first reaches to sector with object versus opposite sector - χ^2 performed

Condition A

Reach	Sector	
	Left	Right
Left	13	3
Right	3	11

$p < 0.01$

Condition B

Reach	Sector	
	Left	Right
Left	13	3
Right	1	13

$p < 0.001$

Condition C

Reach	Sector	
	Left	Right
Left	12	2
Right	1	15

$p < 0.0001$

Accuracy of reaching was determined by taking contacts as a percentage of reaches to the height of the object, i.e. reaches which could have contacted the object had they been accurately directed. Contacts included swipes (or fisting), hitting with the open palm and grasping. Table 4.9 shows the percentage of contacts for each condition.

Table 4.9: Success rate of reaching across conditions in neonates

CONDITION	REACHES	CONTACTS	SUCCESS RATE (%)
A	190	110	58
B	200	90	45
C	161	131	81

The difference between Conditions B and C suggests that the infant is utilising the higher-order information supplied by the guide plus the control aspect available. With B, despite a higher number of reaches the contact rate is lower than in Condition C. The auditory information given in Condition B correlates with some events in the world; however the information content is poor and there is no possibility for control of that information.

Interestingly, performance in Condition C appears to be better than in Condition A. Not only is the amodal information being picked up but it would appear it is of more use than vision. Such a suggestion seems counter to evolution and contradicts any suggestions of visual dominance in early infancy. However, this result can be put in context if we recall the procedure of the experiment. In the visual condition, there was a great deal to look at other than the stimulus object. With the guide condition there is only one meaningful signal coming to the subject's ears - that reflected by the stimulus object. With nothing else competing for his attention, contact rate will remain high.

Arm extension is one component of the reach which can be taken as an indication of expectancy to touch the object. However, the second component of a reach - grasping - is an even more strict indication of such an expectancy. If the subject expects to contact an object, he should grasp at it. Numbers of reaches ending in contact were therefore looked at in detail in order to determine the nature of the type of contact. Table 4.10 shows the sub-division of contacts into swipes or fisting, grasps and palming of the object. These are computed for each condition.

Table 4.10: Breakdown of numbers of contacts into swipes, grasps and palms.

	CONDITION		
	A	B	C
Swipes/Fists	30	47	42
Grasps	72	31	80
Palms	8	12	9
TOTAL CONTACT	110	90	131

As a percentage of contact, there were 65 per cent grasps in Condition A, 34 per cent in B and 61per cent in C. On this measure, again we see that B is much poorer. This can perhaps be explained if we take into account the relatively greater number of swipes (52 per cent) in this condition. A swipe is a fisted hand movement. This can have commenced at shoulder height as a fisted movement <u>or</u> it can be a grasping movement which is imprecise, in other words, a mis-timed grasp. This suggests that the "simplicity" of the auditory signal does not have the same meaning as does the "complex" auditory information provided by the guide or by visual information. The chance of success in contact is low, the success in grasping is lower still. On the contrary, the more precise information as to distance, size, shape, direction supplied by the guide is sufficient to allow success to almost match the success demonstrated with reaching to a visible stimulus.

The above analysis also provides evidence relevant to the reach/grasp sequence. The very few open-handed contacts of the object in all conditions, when compared with fisted or grasping contacts, show the dominance of Phase I reaching. However, Phase I reaching is clearly not specific to a visible object; instead this type of reaching seems to be characteristic in all three conditions, a finding which is in accordance with a theory of differentiation.

It could be argued that, though the neonates show evidence of utilising the direction index of the guide, this is the only amodal property they are picking up from the signal. To investigate this, a small number of neonates were looked at in a further condition to determine their use of the distance index of the guide. If these subjects were picking up distance perceptually, as opposed to operantly, then presentation of the object at a different distance should elicit a change in response. Four subjects were given this additional condition at the end of the normal testing session. Two were presented with Condition A, but with the object at twice the distance of a full arm extension. The two other subjects were presented with the object at twice the distance, but under Conditions B and C. Table 4.11 summarises the results.

Table 4.11: Reaches in within and beyond presentations

REACHES	CONDITION					
	A	A_1	B	B_1	C	C_1
TOTAL	11	3	15	11	17	4
$\bar{x}$	5.5	1.5	3.7	2.8	4.3	1

Reaches were taken as arm extensions to the distance of a full arm extension. For each condition there are two scores e.g. A = 11; A_1 = 3. The first denotes reaches in the within-reach condition, the second denotes reaches in the beyond-reach condition. Firstly, the results indicate perception of the third dimension, thus supporting Bower (1974 b). In both A and C reaching declined with the increased distance. That this was not simply due to fatigue or boredom is shown by the results in Condition B. Despite the increased distance there was only a slight decrement in reaching performance in this condition. Further evidence of distance perception can be shown if we observe subjects when there is no object present in the field. One subject was run in this control in the light and it was found that mid-height activity continued but only one arm extension to the height of the object was observed. This compared with six extensions to the height of the object by the same subject in the main experiment in an equivalent period of time. Secondly, they suggest amodal pick-up of the third dimension, as shown by the results of Condition C.

Thirdly, a comparison of the results in Condition B, with Conditions A and C, suggests use of the additional information available in the latter two conditions. The reason for the continuance of reaching in the beyond condition (B_1) would appear to be attributable to the paucity of information which the passive auditory stimulus provides: loudness of the stimulus does not give a good indication of distance. With the guide, on the other hand, distance is specified precisely by pitch changes.

It could be argued that in the guide condition, reaching to the object after the first reach was merely repetition of a motor response. Although this is somewhat implausible, it is relatively simple to test empirically. For four subjects, after presentation of the object in one position in Condition C, the object's position was changed and reaching observed. Table 4.12 shows the results obtained.

Table 4.12: Results of change of object position in Condition C

REACHES TO	POSITION	
	1	2
POSITION 1	12	5
POSITION 2	6	11

A χ^2 was performed on the results showing a slight but significant trend ($p < 0.1$; $df = 1$) toward the infant changing his response to the new position. If we take into consideration the length of time required for the neonate to organise a responce to the change in stimulus position and the few subjects looked at, such a change in response might well indicate more or less immediate transfer of success, thereby indicating perceptual pick-up of position change.

Taken together, the above results all suggest that the neonate functions with an undifferentiated perceptual system set to pick up amodal stimulation.

The results of this study are relevant to one further issue. It has been suggested that neonate reaching may only be seen in full- or post-term infants (Rader et al, 1979). A sub-set of the data was therefore looked at, extracting those neonates who were one or more weeks premature (range 1-6 weeks). Six subjects were looked at (3 male, 3 female). Table 4.13 shows the results obtained for each condition.

__Table 4.13: Reaching in premature neonates in all three conditions__

RESPONSES		CONDITION		
		A	B	C
REACHING	TOTAL	41	28	41
	$\bar{x}$	6.83	4.67	6.83
CONTACTS	NUMBER	21	16	33
	% OF REACHES	51	57	80
GRASPS	NUMBER	17	5	20
	% OF CONTACTS	81	31	61

Firstly, it can be seen that reaching was obtained with the premature infants. The success rate in contacting the object is quite high, with the guide condition very high. This may be due to there being no other stimulus producing information during this condition. However, that recalibration of the perceptual-motor system is already occurring in the light is shown by the much higher success rate (i.e. number of grasps) in the light versus other conditions. C provides more information for recalibration which B does not, a factor that is reflected in the relatively poorer success rate obtained with B. This observation, that recalibration in light is occurring in very young infants, supports the results obtained by de Schonen (1980) that 3 to 6 day old infants showed improved performance when practised daily on a reaching task. The results with prematures also points out that the development of reaching is not simply due to the maturation of the perceptual-motor system but that environmental input is necessary. This also indicates that the suggestion that neonate reaching is non-functional (Trevarthen, 1975) is incorrect.

AGE-GROUP COMPARISONS:

The results obtained with neonate subjects were then compared with the remainder of the infant subjects. To do this, 6 neonates (3 male, 3 female) were chosen from the original sample so that their reaching frequency conformed most nearly to that of the mean and standard deviation for the total neonate data. Their results were then compared with the results of each group of 6 infants from 2 to 12 months. The number of total reaches for each condition across age is presented in Fig. 4.1 (a) (see over). These results can then be compared with Fig. 4.1 (b) (also overleaf) which shows the percentage of reaches which ended in grasps for each condition for each age group. Any attempt to analyse the results with linear statistics such as linear regression or analysis of co-variance, with age as a co-variate, would be inappropriate. Instead the results will be analysed firstly for any quantitative differences, and then a further qualitative analysis of the reaching will be reported.

Condition A - reaching to a visible stimulus - shows the same pattern as suggested by Bower (1979 a). Initially, reaching is visually elicited and drops out rapidly over the period from neonate to 5 months. Grasping is also much reduced due to the emergence of hand regard, with many of the reaches that were seen ending in fisted contacts. At 5 months and after, reaching and grasping are seen to be differentiated. With the opportunity to direct and control arm transport, plus a slight offset time before initiating the grasp, success rapidly approaches 100 per cent and remains at this level. The latency to reach at this age also decreases markedly to around 1 second.

In Condition B - reaching to an audible object in darkness - we see that the frequency of reaching falls off

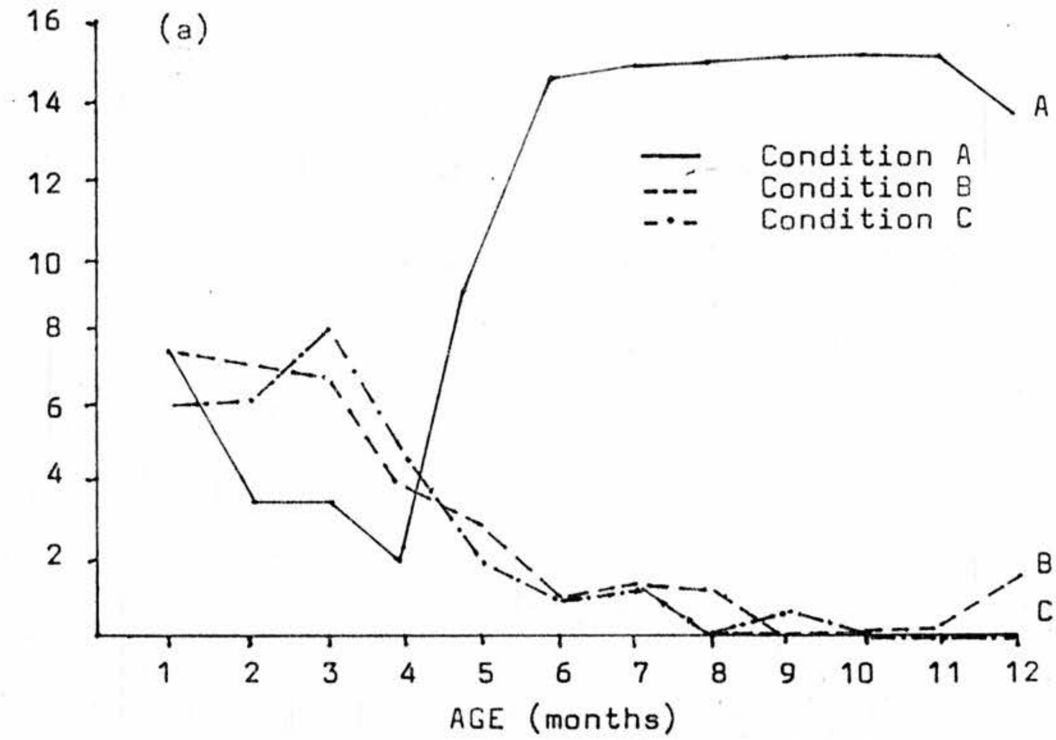


Fig. 4.1(a): Age-group comparisons for sighted infants reaching in Conditions A, B, C

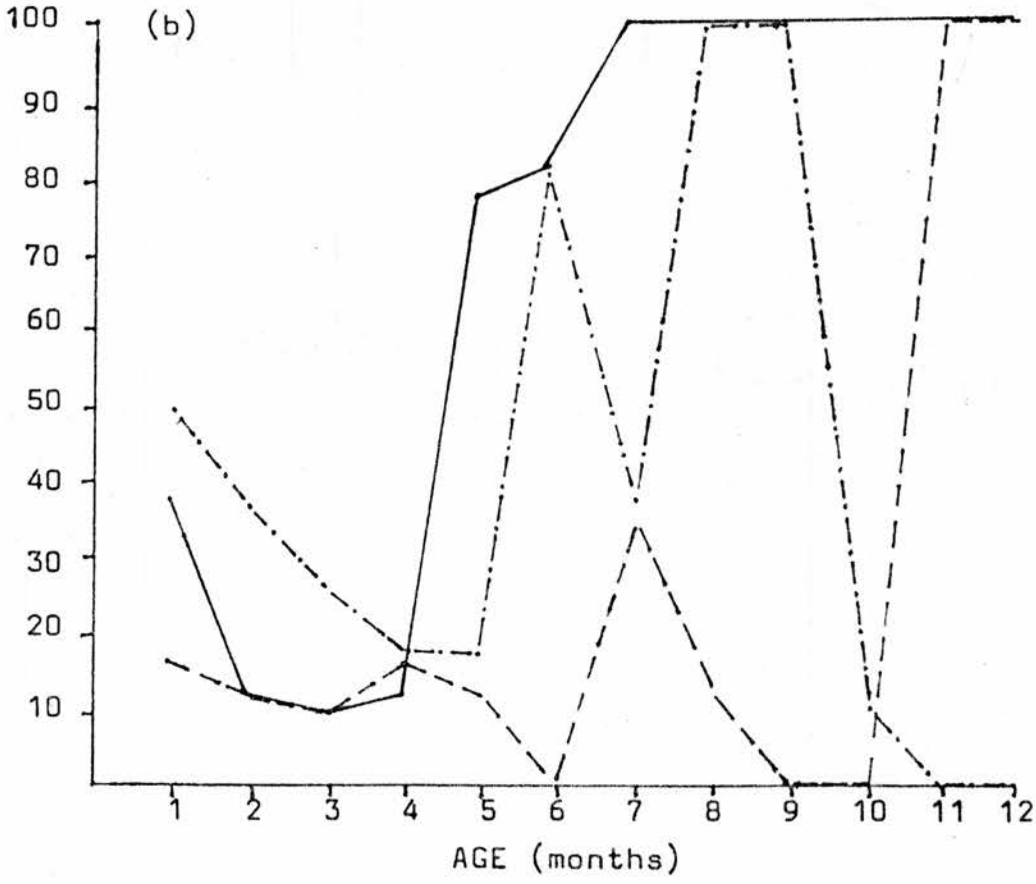


Fig. 4.1(b): Age-group comparisons for percentage of reaches ending in grasps - Conditions A, B, C

much less steeply after the neonate period. Consonant with a theory of differentiation, the increase with age in reaching frequency to a visible stimulus occurs at the same time as minimum reaching to an auditory stimulus. The reaches shown in Fig. 4.1 (a) for 5 and 6 month old subjects all derived from one subject in each age group. Moreover, as is seen in the qualitative analysis later, these reaches occurred only after these subjects had first accidentally hit the object. At 7 months the grasping that was seen was possibly due to an increase in awareness of body schema. At 11 to 12 months we see an increase in reaching frequency in Condition B; this reaching was performed with 100 per cent accuracy (but see qualitative analysis below).

Condition C - the guide condition - shows approximately the same pattern of reaching frequency over age as seen in B. Again, any reaches that were seen with infants older than 5 to 6 months did not depend on Sonicguide information (two infants reached for the object only after they had leant forward and the object had touched the back of their heads, clearly being out of the field of the guide). When we look at the results of the percentage of reaches ending in grasps, we see that the pattern becomes very peculiar with many peaks and troughs after 5 months. In the period up to 5 months, success in reaching is apparently consistently best in this condition. This seeming peculiarity can, however, be explained. In this condition, the signals presented by the guide provide more accurate information as to location and change of location than does the passive sound source. With reaching being ballistic at this age, the accuracy of this information will be of great importance. Reaching under these two conditions will therefore remain at a similar frequency, but the accuracy will be much greater in Condition C than in B. The greater number of distractions in the infants' surroundings in Condition A could account for the difference in accuracy between Conditions C and A; in Condition C the only object in the field of the guide was the fluffy duck.

After 5 months, the pattern of success in grasping in the guide condition seems to become very unusual, with some age groups showing 100 per cent accuracy, others zero accuracy. However, the frequency of reaching remains low. Few infants reached but, with grasping being tactually elicited, accuracy was artificially high. This was related again to an apparent increase in awareness of body schema. The infant would often accidentally hit the object and then reach out, await tactile input and then grasp. After 5 to 6 months, none of the perceptual qualities of the guide was being used, however. The object would often be brought to the ear once grasped. Any change in object position meant that, as far as the infant was concerned, the object no longer existed; no search patterns were seen when the object changed position. Moreover, if the infant did contact the object, no additional exploration of the object was seen using the guide. It would seem, therefore, that quantitative analysis of reaching shows marked age differences in ability to use the guide. These differences conform to a pattern of initial intersensory substitutability with later differentiation of the senses.

Qualitative Analysis: The analysis so far has been quantitative, comparing frequency data and the like. However, it is equally important to look at the type of reach which is performed under the three conditions. Bower (1979 a) has described the reaching of the neonate as visually elicited, giving way at around 5 months to visually controlled reaching as described above. If the information provided was being used in the same way as vision, we should expect the same types of reaches to be seen in all three conditions. To compare these, it is necessary to look at equivalent reaches in all age groups. It could, for instance, be that for an older infant, second and subsequent reaches to an object would be much easier. To compensate for this, therefore, the only reach looked at was the first reach ending in a grasp of the object, i.e. the first successful reach.

In taking the pattern of each first successful reach, the index finger of the reaching hand was taken as a reference point and its position marked at the beginning of the reach on a T.V. monitor and thereafter at every tenth frame of the recording (i.e. at every 0.2 sec.). The points obtained were marked with reference to a point at the base of the object. These points were then copied onto tracing paper and the results for each infant in each condition transferred to graph paper, with side of presentation of object being noted. To obtain group data the median points were taken, resulting in the reaching patterns shown in Fig 4.1 (a-l) (see over). Each figure represents one age group. In each figure are represented all three conditions and, where appropriate, reaches with the object on the right and reaches with the object on the left. To do this, the reference point at the base of the duck was taken as a constant, and median positions superimposed. The twelve figures therefore represent each age group from 1 to 12 months.

As can be seen, the pattern of reach in the neonates corresponds across all three conditions. The same type of reach is being shown in all conditions. All reaches are ballistic. No visual guidance of the reach is apparent. When we look at slightly older infants of 2 to 4 months, we see a slightly different pattern emerging for reaching to a visible object. This is possibly due to the lack of numbers of successful reaches in this condition; in fact, with the 4-month sample there was only one reach/grasp sequence. This figure is therefore somewhat nebulous. However, with the corresponding conditions of B and C, we see that the pattern of the reach remains similar to the ballistic reaching observed in the neonates. The reaching is auditorily-elicited but not guided, similar to the Phase I reaching of neonates, with the reach/grasp being one movement.

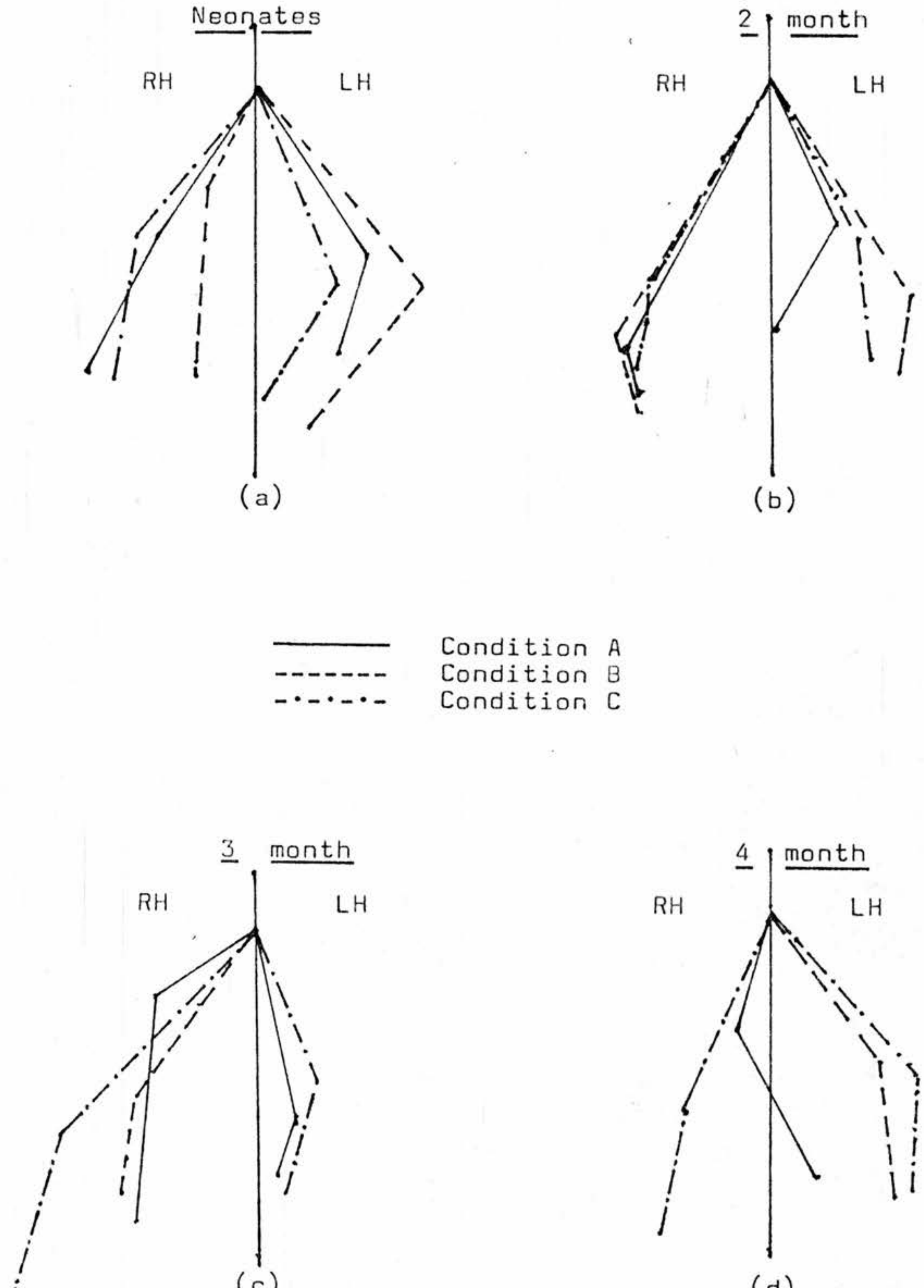
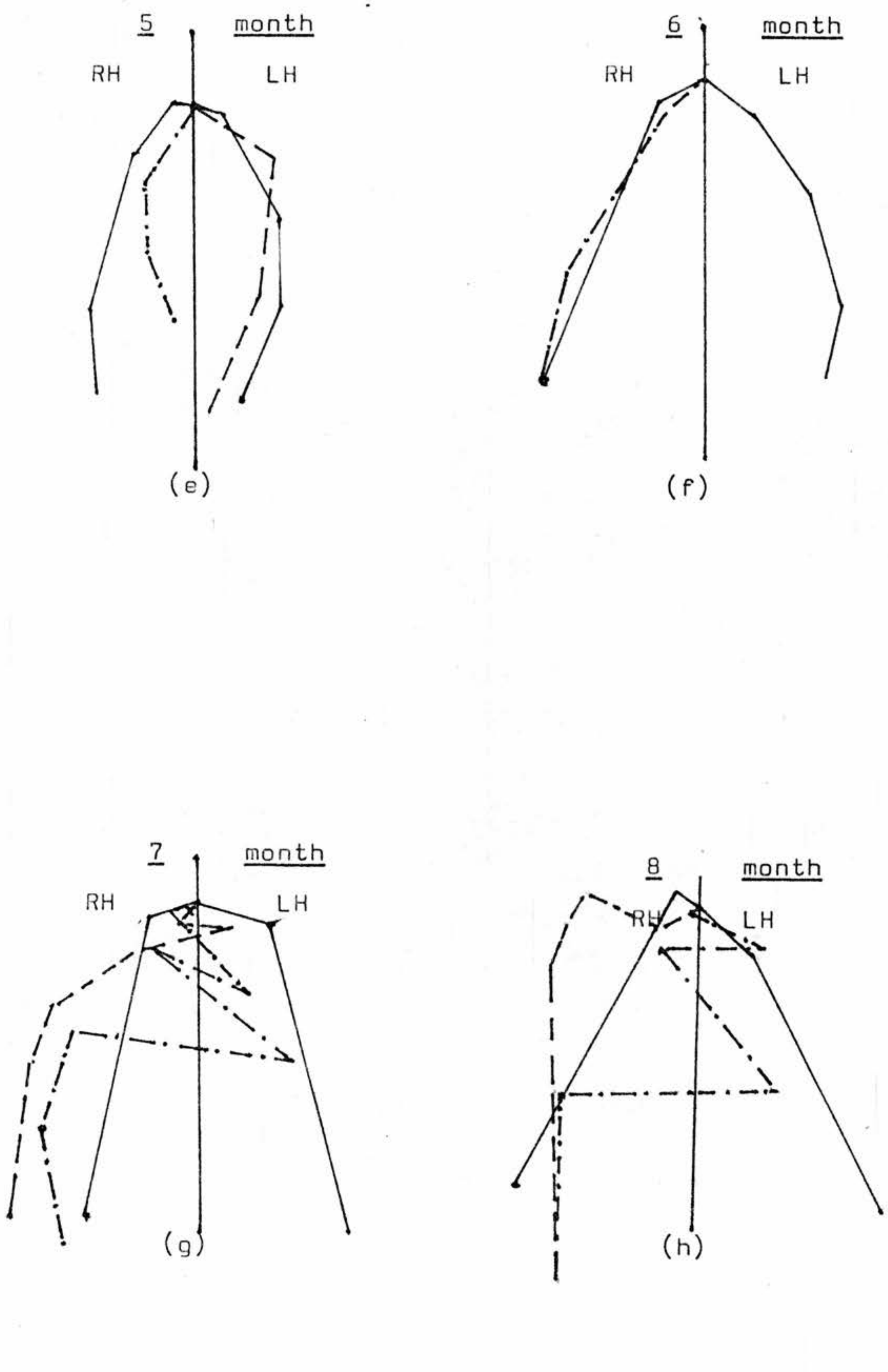
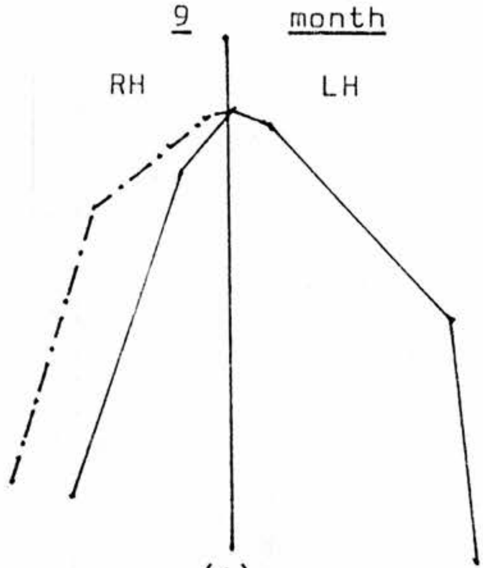
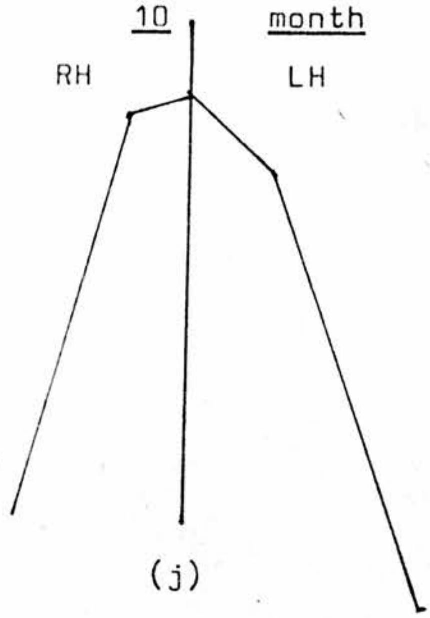


Fig. 4.2 (a-l): Age-group comparisons for qualitative analysis of patterns of first reach - Conditions A, B, C

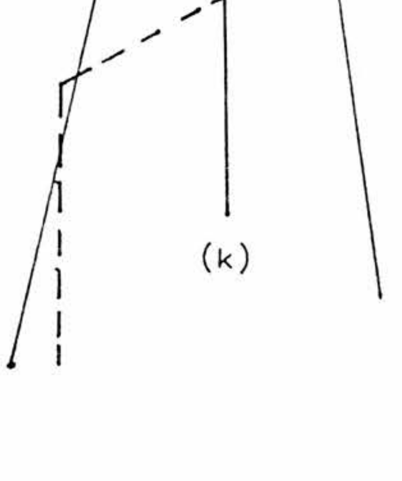

5 month
RH
LH
(e)
6 month
RH
LH
(f)
7 month
RH
LH
(g)
8 month
RH
LH
(h)



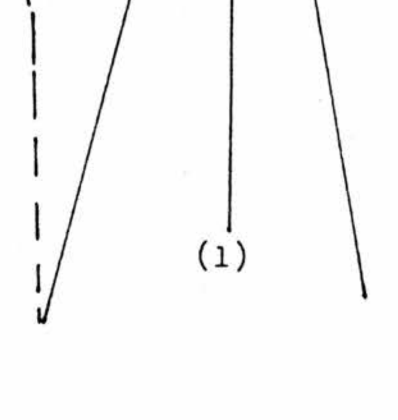
(i)



(j)



(k)



(l)

At 5 to 6 months, we see that reaching in A becomes visually directed. In addition, there are a greater number of positions marked for each reach. This corresponds to the reach taking relatively longer to perform than with the younger infants. As can be seen, there is a slight pause before grasping, corresponding to the positive offset time described by Bower (1979 a). These factors are characteristic of Phase II reaching. There are, however, two other observations at this age. The first has to do with reaching to a noise-making object. As can be seen, this drops out at this age. This replicates the finding of Wishart, Bower and Dunkeld (1978) who also found a pronounced drop in reaching to a sound source at 5 to 6 months. Secondly, though, the reaching obtained with the guide at 5 to 6 months shows a pattern similar to the visually directed reaching of this age-group. Typically the infants of this age would demonstrate searching for the object by scanning movements. Those who did reach in both conditions were equally slow in doing so with the vision as with the guide. It appears then that the emergence of Phase II reaching allows for guidance of the reach under <u>either</u> visual <u>or</u> guide conditions. A controlled reach may be performed using either vision or the guide. The information and control necessary to enable Phase II reaching to proceed are not, however, present in the passive sound source condition, a reason perhaps why reaching drops out in this condition.

With the 7 to 8 month olds, we see that in the visible stimulus condition reaching is still under visual guidance. The initial arm extension is very rapid, with a pause at the object before grasping. This also replicates Bower's (1979) finding of the reach-then-grasp sequence in this age-group. However, if we look at Condition B, we see that reaching consisted more of what could be described as groping. In addition, no fixation of the appropriate sector was observed during this reaching, with reaching only occurring after the object had been contacted by another part of the body. A similar result was obtained in Condition C. In this case, grasping again only occurred after accidentally contacting the object. In one case, the object touched the back of the subject's head, was reached for, and then taken to the subject's ear. In no case was additional exploration carried out with the guide. For this age-group, the guide signal appeared to be merely a sound in their ears, having no informational value.

With those infants 9 to 10 months, the pattern of reaching in the light was like that of the previous subjects. No reaching was observed in Condition B. From the pattern of reach in C, however, it appears that the infants in this condition were as able to make us of the guide information as visual information. However, on closer analysis, it could be seen that this similarity in reach pattern was only true of those reaches occurring after the infant had first contacted the object accidentally. The reason for the reach taking less time (i.e. there being fewer number of points in the reaching pattern) is possibly due to the increased awareness of body schema.

With the infants 11 to 12 months, no reaches were seen in C, in fact all of the infants at this age were very distressed by the guide, two of them clutching at their ears. In Condition B, we see that successful reaching is beginning to re-emerge. In these cases the reaching was successful without there being the need for prior accidental contact.

On both the quantitative and qualitative measures of reaching there would appear then to be much poorer use of the guide after the age of about 5 to 6 months. To investigate further the nature of this transition, other measures of search were looked at. It was reported above that the reaching seen with the 7 to 8 month olds occurred only after these infants had first contacted the object by accident. With several of the 5 to 6 month olds, however, it appeared that they attempted to control the information supplied by the guide. It seemed that they were using the signals as information rather than as sounds but they did not know what to do with this information since it did not conform to the sort of auditory information they normally experienced.
To test for any use of the information in searching, the scanning and fixation patterns of infants 5 to 12 months were looked at in detail. In any one session, the amount of time infants spent in fixating the appropriate sector was measured, and compared with the amount of time spent both in

head movements and fixations of the opposite sector (midline position was included in the latter). The results of this analysis are given in Table 4.14.

Table 4.14: Sector fixation in Conditions B and C
(As a percentage of total time)

CONDITION	AGE GROUP							
	5	6	7	8	9	10	11	12
B	40	32	28	50	31	35	35	46
C	77	70	55	41	30	35	31	22

The results show that, despite little reaching being seen with the 5 to 6 month olds, they spent a significantly longer time fixating the sector containing the object. For the passive sound condition, there was no such pattern. With the 7 to 9 month olds, despite there being a few reaches and grasps, there was no related fixation pattern. Sounds by then seemed to be something to be listened to, as was evidenced by more than one subject accidentally hitting the object, and then bringing it to the ear. These results are in accordance with the type of differentiation account put forward by Bower (1979 d). In this account, sensory specificity is overlaid on the undifferentiated perceptual system. The higher-order information is retained but becomes overlaid by sensory specification, not replaced by it. The reason that the information presented to the 5 to 6 month group by the guide can still be used for "search and locate" but not "search and reach for" is quite possibly due to the success of reaching now being experienced in the visual modality. Index of position and position change remains invariant but for the infant is becoming specified for the visual modality. By 7 to 8 months, the content of the signals produced by the guide has, for the infant, no informational value. No control of auditory information has been experienced in the past and therefore there is no reason for the infant to make use of such control.

There is, however, some evidence for its use at this age as an operant signalling device. One 8 month old, after accidentally hitting the object, (with the back of her head) batted the object away. She then reached out to the position the object had been in when she had last touched it, resulting, of course, in failure. When she did eventually grasp it, it was immediately brought to her ear. It is interesting to note that, with the older infants, despite occasional accidental contact of the object (i.e. without use of the specific qualities of the guide), no consonant increase in fixation of the object was observed. The contact with the object and the signals produced by the guide were for them not associated. In contrast, the 5 to 6 month olds, while not reaching, would spend a great deal of time in fixating the object and making slight head movements, seemingly exaggerating parallax cues to enable edge detection. All this would occur without any attempt to reach or touch the object.

This argument can be extended to the neonates. If the neonate subjects are showing least sensory specificity, then we should find that most reaching responses occur while fixating the object position. This was computed and it was found that in Condition A, 89 per cent of reaches were performed while fixating the appropriate sector; for B, 78 per cent; and for C, 83 per cent. This demonstrates that the centralising of a stimulus is not peculiar to vision (i.e. foveation). Instead it appears that centralising provides maximum pick-up of amodal information whether through light, sound or touch. Foveation is a sensory-specific correlate of the centralising of any physical stimulus.

DISCUSSION:

The results presented in this analysis have, it is felt, implications for a number of areas of development. Not all of these areas appear at first to be related to a theory of differentiation. Firstly, the reaching behaviour observed with neonate subjects contradicts the findings of researchers such as Field (1977), Dodwell et al (1976) and Ruff and Halton (1978). The strict criterion of reaching adopted here shows that reaching is in fact present in neonates. Reaching was observed to be directional, with compensations being made for changes in position and distance. Furthermore, the suggestion made by Rader (1979) that reaching can only be observed in post-term infants was not upheld. Neonates up to 6 weeks premature demonstrated reaching in this study. The type of reach obtained was seen to be a ballistic reach-and-grasp with the components of arm extension and grasping being unseparated. This evidence supports the analysis given by Bower (1977 e; 1979 a) of the Phase I reach of the neonate.

Secondly, this study provides evidence for perception of the third dimension in neonates. The reaching observed was calibrated for distance. Yonas et al (1977) have argued that a looming response to impending optical collision does not necessarily indicate innate perception of depth but may well be a learned response; the infant, for instance, may previously have been hit on the face by the mother's breast. This criticism could also be levelled at the reaching in the light observed in the present study. However, such an explanation is unlikely in Condition B and impossible in Condition C. It is possible, though extremely unlikely, that accidental contact with the object enabled further successful contact to be made in either of these conditions. This could not be argued in the control condition using a within/beyond reach stimulus (see Table 4.11 above). That the reason for a drop-out in reaching in A_1 and C_1 (when the stimulus was not in reach) was not simply due to failure to contact is shown by the results in B_1. From B to B_1 there was a slight drop. Reaching remained higher than A_1 and C_1, however, indicating that the information indexing distance presented in this condition was very poor. Simple learned associations to distance information can therefore be discounted. (Unless learning is occurring much more rapidly than current theories of learning suggest - a possibility which is considered in Chapter 6.) Perception of the third dimension would appear instead to be an innate capacity. What is learned is the recalibration necessary as a result of growth. The invariants of "straight-ahead" and right/left remain, as does the "out-thereness" of the third dimension. Recalibration within these invariants goes on during development. It would seem that there are perceptual invariants but not, as Held has suggested (Held, 1965), perceptual-motor invariants.

Thirdly, these results confirm the suggestions of Bower (1979 a) concerning auditory localisation. He hypothesised that any perceptual ability which depends on structures and/or stimuli as properties that do not change as a result of growth will be present at birth. The present neonate results in Conditions B and C confirm this, with the same invariants for audition as for vision and with the same recalibrations across these invariants.

Fourthly, the results are significant for theories of the development of reaching. The initial ballistic reaching seen in all conditions was replaced by visually directed reaching at around 20 weeks. This supports the work of Bower (1977 e), Bruner and Koslowski (1972), McDonnell (1975, 1979) and von Hofsten (1977, 1979), while disagreeing with the positions held by White, Castle and Held (1964) and Field (1977). Interestingly, the frequency of Phase I reaching observed in Condition A dropped considerably after 4 weeks of age. This is in accord with previous work. However, it did not drop in Conditions B and C. Reaching frequency from 1 to 4 months remained almost as high in C as in neonates as did success in reaching (as measured by grasping). Frequency did diminish progressively in B, with a more marked reduction in accuracy. The saltatory change at around 4 weeks seen in the light was not, however, seen in B and C. This would discount a maturationist account of the drop-out in reaching; if reaching decreased due to changes in brain structure for instance, we would expect to see the same drop-out in all conditions. Instead we must look elsewhere for an explanation for the decrease. It is possible that an explanation may be related to the fact that emergence of Phase II reaching in the light co-incided with drop-out of reaching in the dark. In addition, the reaching that was observed in Conditions B and C up to 5 months was characteristic of Phase I reaching. At 5 to 6 months, however, we see that the emergence of Phase II reaching occurred in both A and C. It would appear from this that the emergence of Phase II reaching is maturationally determined. What then causes the reaching under B and C to disappear at this point?

It seems that an answer to this question may, as was said, tie in with our previous observations on the development of auditory-manual co-ordination, visual-tactile co-ordination and amodal perception of invariants. It is felt that a theory proposing differentiation of the senses at around this age could well account for these observations. The first observation made concerning the visual-manual co-ordination of the neonate is certainly in line with a theory of differentiation. The infant orients to the visual stimulus with an undifferentiated reach/grasp. A theory of differentiation is also consonant with the second observation previously mentioned concerning distance. For the infant to reach out he must firstly be able to perceive distance. Also he must be able to perceive direction. As was shown, there is strong evidence for the perception of both of these higher-order properties of information in young infants. There is also strong evidence suggesting that invariants of these higher-order properties are picked up by neonates. These invariants seem to be picked up amodally without reference to a particular sensory modality.

A differentiation theory therefore seems to explain most of the observations made above. It explains, for instance, the dissociation between vision and touch which occurs at 5 to 6 months, a process which also seems to affect auditory-manual co-ordination at this age. However, it does not appear to account for the difference in reaching rates in presentation requiring visual-manual (A) and auditory-manual (B) co-ordination, from 1 to 5 months. If differentiation were due simply to maturational influences, we would expect reaching rates in these conditions to be similar. To account for differentiation as a process, we must either look for some environmental influence or some interaction of the two. If we look firstly at the results of reaching to a sound source (B) and reaching with the guide (C), we see that accuracy of reaching (grasping) remained quite high in C and progressively diminished in B. Auditory-manual co-ordination therefore still existed and the senses were not as yet dissociated. Moreover those successful reaches that were seen in B and C prior to 5 months of age were of the Phase I undifferentiated type. The few successful reaches seen to a visible stimulus (A) were also of the Phase I type in this age group. It seemed, therefore, that visual-manual co-ordination was still present. The presence of both of these co-ordinations follows if the young infant is living in a unified perceptual world where seen objects are touchable, heard objects are touchable and so on.

This being so, the question remains as to why both the frequency and accuracy (as measured by either contact or grasping) of reaching decreased in the light. It would seem that there is no need to put forward maturational accounts for the decline in frequency once it is realised that the likelihood of successful grasping with Phase I reaching is very limited. This type of reach and grasp requires precise timing since arm transport is not as yet visually controlled and directed. This would suggest that the decrement in Phase I reaching to a visible object occurs not as a developmental phenomenon, but is merely extinguished due to lack of success. If so, we would expect that the extinguished response could be re-elicited given appropriate opportunity with a rigid, stationary object. Bower (1979 a) has shown that Phase I reaching can indeed be regenerated if the infant is given the opportunity to exercise it in this way. Even when the success of Phase I reaching is enhanced, however, Phase II reaching still seems to emerge at about the same age as it is seen to emerge when the success of Phase I behaviour is not enhanced. The event which seems to facilitate the emergence of visually directed reaching appears to be the onset of hand regard. With this the infant's hand in his visual field becomes an object, an object which can be reached for and grasped by the other hand.

Bower (ibid.) has also suggested that the changeover to visually directed reaching is not in fact a developmental change as it is not an irreversible change. Given the appropriate circumstances, visually elicited reach-and-grasps can be observed in Phase II infants. The evidence presented in this study, though, would at first appear to suggest that the change was indeed truly developmental in that the sonic-guide equivalent of visually directed reaching emerged simultaneously with controlled reaching to a visible stimulus. This can be seen from the analysis of reaching pattern seen in Fig. 4.2. It is argued, however, that rather than offering evidence of irreversibility, this can be explained by the type of differentiation account being presented here. It cannot be explained by a Wernerian account in which Phase

II would directly replace Phase I with the change being irreversible. Instead the antecedent, more undifferentiated mode is contained in the second more differentiated mode - i.e. Phase II incorporates Phase I but the latter, being less successful, is rarely produced. The change is not, therefore, a U-shaped change in the Wernerian sense but simply functional change based on the increased likelihood of success of the differentiated mode of reaching.

With lack of both practice and success with the sonicguide, Phase II reaching is not sustained in this condition. The emergence of the new behaviour is not enough. Its emergence must also be coupled with its use, otherwise the behaviour dies out. This is also shown in Condition B. The lack of information given by a sound-making object, plus the specification of audition for listening to sounds (thereby facilitating language development), leads to the extinction of auditory-manual co-ordination.

It would appear that in the results of the 5 to 6 month group, we may have evidence of an actual example of this process of transition. It will be recalled that at this age only a few reaches were observed. These reaches were visually controlled. However, in addition to the search-locate-grasp that was observed, there were some subjects who evidenced only search-and-locate. It seemed that the higher-order information properties of the guide were being used by these subjects only to scan for and then fixate the object. Use of the information content had become differentiated from the now visually specified reach-then-grasp. This then is an example of differentiation without loss. The informational value of the signal has been retained but this amodal pick up has been overlaid by a sensory-specific response. At 7 to 8 months, the "out-thereness" of the signal is also overlaid, this time by the sensory-specific response of simply listening to the sound. The signal of the guide is still recognised as information by the infant, as seen by his immediately stilling and listening to the sound. The meaning of that information has, however, changed for the infant, it is now modality-specific.

CONCLUSIONS:

Adopting a more rigorous experimental approach than is possible when working with blind infants, the evidence presented in this chapter has shown that a theory of differentiation in perceptual development does have validity. Despite empirically tipping the balance in favour of finding more effective guide use in older subjects, it was found that the younger subjects showed greatest facility in use. The evidence points to this use being based not on operant parameters - at least not in terms of our current knowledge of rapidity of learning - but on amodal use. Allowing older subjects access to more information provided no evidence of any advantage in guide use over young infants, to whom no prior information could be given. The evidence presented so far does, however, suggest that use of the Sonicguide may follow a U-shaped developmental function. Initial perceptual guide use appears to disappear at 5 to 6 months. Any re-emergence of use at a later age appears to be based on an operant mode, with laborious re-learning being required. At worst, it may drop off altogether. This would appear for practical work to have very pessimistic implications. If true, it means that any gains in guide use before 5 months would then be lost. If true, it also has theoretical implications. Throughout this thesis an epigenetic model of development has been argued for, with interaction between maturational and environmental influences. If guide use dropped out at 5 months not to be re-established, this would indicate that any argument for redirection of development by environmental input - i.e. the Sonicguide - would be untenable.

To explore this argument further, it will be necessary to look, not at one-off users, but at long-term users of the guide. The next chapter reports this work.

CHAPTER 5 - LONGITUDINAL STUDY OF SIGHTED INFANTS' USE OF THE SONICGUIDE

INTRODUCTION:

Investigation of the protracted use of the guide could have both applied and theoretical implications. If use of the guide is consistent or improves, this would provide information as to the frequency it is necessary to wear the guide as well as the amount of time required. Watson (personal communication) has suggested that perhaps as little as ten minutes per week or per month is sufficient. This type of study avoids the research problems associated with working with blind infants and might go some way towards indicating how the guide could best be utilised in ameliorating the development of the blind child.

As well as having practical implications, the results of this study will be of theoretical interest. They will provide information as to the relative contributions of maturational and environmental inputs in development. It has already been pointed out that their relative influences are always extremely difficult to assess. The use of a completely novel environmental input, one which the infant has had no opportunity to use outside of each experimental session, provides one means of assessing their relative contributions. In a longitudinal study there are a number of additional predictions which can be tested and may lend support to one or other of the different interpretations of perceptual development outlined previously. For instance, direct testing of the overlay hypothesis versus the replacement hypothesis of differentiation in development can be made. The former hypothesis, put forward by Bower (1979 d), argues that modal response overlays amodal response, but does not replace it. The latter, the Wernerian account, proposes that the synaesthesic (or undifferentiated or "global") response is followed by differentiation and then is replaced by modally specific responses after a period of re-interpretation. With the Sonicguide used in a long-term study, we will be able to observe the protracted use of the guide and determine whether initial amodal responses are overlaid by modal responses or replaced by them.

The justifications presented in the previous chapter for looking at use of the guide by sighted infants in the dark remain valid for this longitudinal study. Additionally, however, we are biassing against the possibility of demonstrating later use of the guide. This is because the sighted infant's world becomes more and more visually dominated as he grows older (Rock and Harris, 1967). The chances of obtaining use of the guide would seem, therefore, to decrease with age, especially if the guide is only to be worn once or twice per week. However, a long-term study provides a further advantage. One criticism that could be levelled at the results of the previous study with older infants seen cross-sectionally was that they may have been upset by being in the dark. Accordingly, any lack of use of the guide would not be due to a differentiated sensory system but simply to the fact that the infants found the entire experimental session disturbing. Also, the previous study did not (and could not) demonstrate whether Sonicguide use could be established by a period of training in subjects in whom initial use was not "perceptual". The present study was therefore designed in an attempt to answer the above questions.

METHODOLOGY:

Two sets of longitudinal studies were initiated, each of which attempted to answer different questions. These studies will be discussed in turn.

SEMI-LONGITUDINAL GROUP:

Design: One of the aims of this study was to control for a"session effect" as described above. It was thought possible that older infants may not have used the guide because they were upset by the experiment per se. This was somewhat unlikely as some of the older infants in the previous study had shown that they would reach in the dark to a passive sound source. Their non-response seemed to be specific to the guide condition. Nevertheless, to discount this remote possibility, a few babies were observed an average of once a month, beginning at different ages.

Secondly, this study provided an opportunity to look at any "training" effect (for qualification of "training" see below). It is possible, despite there being no perceptual use of the guide, that these older infants would learn to use it over several sessions, even though the sessions were widespread. This gives the additional opportunity of investigating a type of intervention programme which is easy to implement. This type of programme is one where "intervention" is extremely limited, being closer to a programme of non-intervention than intervention. One approach to Sonicguide work with blind infant would be to give the infant the guide and then simply observe. There would be no training with the guide. It could be that this approach would be feasible with young infants who, as it was shown, seem able to use the guide perceptually. With older infants, the potential for its use may remain, but as a result of sensory overlay through differentiation, this potential is no longer on an amodal basis, but on a learning basis. The question we can then investigate with this group of subjects is whether learning to use the guide can take place without training, i.e. through simply giving the infant the guide. Again, an investigation of this type would be - or should be - impossible to carry out with blind subjects.

The task looked at with these infants was again the search task, as described in the previous chapter.

<u>Subjects</u>: From the sample of infants in the cross-sectional study one infant at each age of 4, 6, 8, 10 and 12 months was observed, at monthly intervals.

RESULTS AND DISCUSSION:

Table 5.1 shows the results of the search task with these infants. Only the condition involving the Sonicguide was carried out.

Table 5.1: Results of search task with Semi-Longitudinal group

AGE GROUP	VISIT	REACHING BEHAVIOUR						FIXATION OF CORRECT SECTOR
		L	F	SECTOR OF FIRST REACH		CONTACTS	GRASPS	
				Correct	Wrong	%	%	%
4 Month	1	24	6	4	2	50	0	65
	2	150	4	4	-	75	75	71
	3	360	-	-	-	-	-	76
	4	360	-	-	-	-	-	48
	5	360	-	-	-	-	-	31
	6	360	-	-	-	-	-	38
	7	360	-	-	-	-	-	45
	8	360	-	-	-	-	-	29
6 Month	1	15	5	5	-	100	100	70
	2	360	-	-	-	-	-	59
	3	360	-	-	-	-	-	41
	4	140	1	✓	-	100	100	38
	5	360	-	-	-	-	-	26
	6	360	-	-	-	-	-	40
8 Month	1	360	-	-	-	-	-	12
	2	360	-	-	-	-	-	29
	3	360	-	-	-	-	-	36
	4	360	-	-	-	-	-	30
10 Month	1	360	-	-	-	-	-	33
	2	360	-	-	-	-	-	28
	3	360	-	-	-	-	-	41
12 Month	1	360	-	-	-	-	-	35
	2	360	-	-	-	-	-	30

L = Latency F = Frequency

Reaching behaviour is looked at under the same categories as in the last study. Time spent fixating the appropriate sector is shown in the right-hand column. This is given as a percentage of the total time spent in the session.

Several clear trends can be seen to emerge from these results. Firstly, none of the infants aged 8 months or older showed any reaching to the sonically specified object on the first visit, nor did they show any improvement on any subsequent visits. Fixation of appropriate versus inappropriate sector was also looked at, as it was possible that these infants could be searching with the guide but not reaching. This proved not to be the case; there was no difference in fixation of appropriate versus inappropriate sector and again no improvement after several experimental sessions.

The first session with the 6 month old subject shows sector appropriate reaching as well as increased fixation to this sector. In addition, reaches were sonically directed i.e. they were characteristic of Phase II reaching. The implications of this were considered in the last chapter. With this child, it appears that there is a U-shaped curve in guide use. No use was seen at 7 to 8 months. At 9 months, however, on the fourth visit, an accurate reach was seen. On closer analysis, however, it was seen that this was not due to any increased facility or re-emergence of guide use. Instead, reaching was accidental and due to an increased awareness of body schema - again a topic that was discussed in the previous chapter. Furthermore, in this and subsequent sessions no related increase in fixation of the appropriate sector was seen, no increase in exploration of the object by the guide.

The pattern of guide use in the 4 month infant is clearer. At first, none of this subject's reaches culminated in a grasp, despite 50 per cent of them ending in contact with the object. At 5 months (visit 2) reaching was seen to be sonically directed (Phase II type) as before. An increase in both contact and grasping was observed. This fits in with the observations of cross-sectional 5 to 6 month old subjects described in Chapter 4. At 6 months, (visit 3) we see that reaching dropped out completely. Nevertheless, fixation remained to the appropriate sector which could suggest a transition period for sensory differentiation. In this case, it seemed as if the infant still found the guide signals to be of informational value, but since this conflicted with what usually happened with passive sound sources, reaching was no longer elicited. Thereafter no further reaching or scanning (as measured by fixation patterns) was seen in any of the next five visits. This could also be consistent with the Piagetian idea of a developing "scheme". A scheme is an action sequence which is appropriate to a particular class of stimuli, that is dependent on a specific type of stimulus input. This input could be sight or sound or touch. In this case, with the change in reaching occurring at 5 to 6 months, the action sequence emerging could be seizing only on visual information as the specific stimulus input for that scheme.

These results answer some of the problems outlined above. Firstly, by controlling for a possible "session effect", it is shown that lack of guide use in later ages of the cross-sectional study was not due to "stranger fear" (of the experimenter), separation anxiety (as a result of the conditions of testing - total darkness) or some age-linked affective factor. Instead the results point to a genuine difference in ability or competence which could well be due to sensory differentiation i.e. the overlaying of modal responses on to amodal responses. Secondly, opportunities to use the guide once per month did not seem to lead to any improved effectiveness of use. There are two possible reasons for this. The first is that use would have dropped out in any case and cannot be re-established no matter how many sessions are run. The second possible reason is more optimistic in practical terms. This is that use dropped out simply because there was a lack of opportunity to use the guide. This would suggest that by increasing the frequency of use i.e. more experimental sessions, guide use can be maintained.

There is a third conclusion which could be drawn from these results. This is that this type of approach without training, i.e. purely observational, is not effective. This has implications for Sonicguide work with blind infants. It would suggest that, when working with infants who are not using the guide amodally as a perceptual surrogate, intervention must be structured, involving active training sessions, and must not be purely observational.

LONGITUDINAL GROUP:

This study was a more conventional longitudinal study involving once-weekly or twice weekly experimental sessions with the guide. The aims of this study differed slightly from that of the previous, semi-longitudinal study. The practical aim was to provide information which could eventually be useful in determining whether behaviour could be normalised in the congenitally blind to any extent. To do so, it would be necessary to determine which if any behaviours would emerge with guide use and if any of them represented behaviours which would not normally emerge in the blind. It could be that some behaviours would not emerge at all despite prolonged guide use. The theoretical aim closely followed the practical aim. If the guide was able to programme development, it would be necessary to investigate how this was done. This requires that the study looks at developmental processes, i.e. how development is proceeding. This requires that we look at the epigenetic process to determine how the information from the guide is being used, that is, what the meaning of the information is to the infant and how this meaning may change.

METHODOLOGY:

Subjects: Six subjects were selected from the neonate group of cross-sectional subjects. Table 5.2 gives the details of each subject. All but one of the subjects was a first-born.

Table 5.2: Demographic data on longitudinal sighted subjects

Subject	Sex	Birth Order	Birth	Frequency (per week)	Age (Chronological) at first visit	Conceptual Age at first visit
AH	M	1	on time	2	3.0	43.0
MM	M	3	- 6 wks	1	3.0	37.0
ES	M	1	- 1 wk	1	2.1	39.0
KB	M	1	on time	1	1.2	41.2
RG	F	1	on time	1	2.4	42.4
SK	F	1	- 4 wks	1	1.4	37.4

As can be seen, three of the subjects were premature; one of them, 6 weeks premature, was the most premature infant seen in the cross-sectional sample. Frequency refers to frequency of visits to the lab - either once or twice a week. Age at first visit is given for both chronological age and conceptual age. The frequency of visits by the mothers and infants was constrained solely by parental willingness. Only one mother (mother of AH) could guarantee twice-weekly visits. The others, as will be seen, found difficulties in keeping to a once-weekly schedule. Subjects were seen then either once per week (five subjects) or twice per week (one subject) for between eleven and fourteen months. The difference in frequency of visits was determined solely by whether the mothers felt they could keep to such a schedule. Visits were scheduled to keep as closely to the intended frequency as possible. If breaks occurred, for example for holidays, then sessions resumed as soon afterwards as possible. It was felt that this arrangement was quite satisfactory as similar breaks could occur when working with blind subjects.

Design: Because of the rapport built up with the parents during these sessions, plus there being little or no time constraints on length of experimental session, a variety of techniques for assessing guide use could be utilised. Where appropriate, these techniques and the rationale behind them are discussed more fully at the appropriate point. The disadvantage of Sonicguide work carried out longitudinally is that a very large number of behaviours could be looked at. Selection of classes of behaviours was therefore done on the same basis as described in Chapter 2. The behaviours looked at then, and again in this study, were confined to defensive responses, reaching, tracking, social games, locomotion and object permanence testing. It was felt that this range of behaviours would be sufficient to determine effectiveness of use of the guide.

Individual performance profiles of each subject will be given. Comparisons between subjects will mainly be drawn later, in the discussion of the results.

<u>Subject KB</u>: This subject was seen weekly up to the age of 19 weeks. At this point, the parents moved away and visits were reduced to approximately one every two months. This subject therefore served to provide further information for establishing whether reduction of visits eliminated Sonic-guide responses. Reaching frequency diminished gradually from 4 to 12 weeks, after which it dropped out for two weeks and reappeared as 60 per cent Phase I, ballistic, 40 per cent directed reaching. At 16 weeks, this became 100 per cent Phase II reaching, with 100 per cent success in contact. From 4 weeks to 14 weeks, grasping diminished sharply. At 12 weeks sonically elicited "hand regard" was obtained. In this case, the infant waved his hand in the field of the guide and "tracked" it by head movement when it moved out of the field of the guide. Change of position of the object elicited appropriate change in direction of reaching responses. At 11 weeks, the stimulus (the fluffy duck) was moved slowly (2 cm/sec) from left to right and back. Appropriate tracking movements were obtained. This was repeated five times, each time obtaining the appropriate tracking response. At 12 weeks he was sat in a baby chair (reclining at 30°) and an object brought to and from his face without touching it. This was performed ten times; two appropriate defensive responses were obtained. A further test was performed with this subject to determine whether guide use was perceptually based. For this, reaching to the object was first established and then the short-

range guide (see Chapter 1) substituted. If the guide were being used perceptually, we would expect to see a mis-reach, as the signal produced by the object (still at its original position) would appear to the infant to designate a different position. If, on the other hand, the infant was simply sweeping his hand and then contacting the object, without using the specific qualities of the guide, we would expect him to contact the object as before, with no disturbance in reaching. (This is somewhat akin to presenting an auditory equivalent of a prism experiment under conditions of vision). It was found that under these circumstances, the infant mis-reached, apparently having calibrated distance with pitch change. Direction of the reach was to the appropriate sector but incorrect in depth. This test was performed during two sessions, at 6 and at 18 weeks. On both occasions, testing had to be terminated due to upset after only one minute. It is not clear whether the upset was due to the infant mis-reaching i.e. a measure of a violation of expectancy, or whether it was simply due to fatigue.

After 19 weeks of age, this subject made four further visits at intervals of on average two months. No further Sonicguide responses were obtained on any of these occasions. On the last two sessions, he was so distressed by the sound of the guide that he would not participate in the session. On these occasions, he was quite content to sit in the dark and listen to a passive sound source and would reach out for it with tactilely elicited grasping.

<u>Subject MM</u>: This subject was seen weekly from 3 weeks up to the age of 12 weeks. At this point contact was lost with the parents and only re-established at the age of 7 months when weekly visits resumed. It will be recalled (see Table 5.2) that this subject was 6 weeks premature. The early sessions of this subject therefore afforded the possibility of investigating the relative influence of maturational and environmental factors in determining reaching progression. As reported in Chapter 4, results with this subject contradicted the predictions of Rader et al (1979) that neonate reaching is only obtainable from post-term infants. However, it is still possible that maturational influences are relatively more important in neonate reaching. If so, we would expect to see an <u>increase</u> in reaching up to the point where this infant's conceptual age was 44 weeks (the equivalent for a full-term infant of 4 weeks of age - the point at which neonate reaching normally drops out). If, on the other hand, environmental influence decreases reaching responses (because of the poor success rate of Phase I reaching) then we should see a progressive <u>decrease</u> in such responses from 38 up to 44 weeks conceptual age. Table 5.3 shows the change with age up to the tenth visit for reaching. Six weeks of chronological age (visit 4) marks the point of full-term conceptual age, ten weeks of age is therefore equivalent to the infant being 4 weeks of age (when corrected for prematurity).

Table 5.3: Reaching frequency over a 10 week period for Subject MM

Frequency	Visit no. 1	2	3	4	5	6	7	8	9	10
Reaching	1	6	12	3	10	12	6	7	4	2
Contacts	1	4	10	2	4	10	4	3	2	1
Grasps	1	4	7	2	2	4	2	2	1	1

As can be seen several patterns emerge. In terms of reaches only, frequency is rather variable up to visit 8, which would fit in with both an environmentalist and nativist position. On the former, the increase would be seen as due to maturation of perceptual-motor co-ordination. The balance would seem, however, to be tipped towards maturational factors as the reaching frequency does not decline sharply at visit 4 but declines at visit 8, when MM was 4 weeks old (corrected). Thereafter reaching is consistently lower. If taken in isolation, this would seem to suggest that maturation is all important in the development of reaching. If adopting this view, we could then postulate that the reason for the decline and then re-appearance of reaching between 4 and 20 weeks was perhaps due to structural changes in the brain.

However, the results of previous reaching studies described in the last chapter (e.g. Bower, 1977 e; 1979 a) would urge caution in this type of interpretation. The results obtained here would also suggest another interpretation, once we consider aspects of reaching other than arm extensions. If we look at reaches which ended in grasps of the object, a different pattern emerges. Here we see that grasping, as a percentage of reaches, remains high in visits 1 to 4. This again could be explained by either maturational or environmental arguments. At visit 5, however, we see that grasping is markedly reduced and remains so, through to the final visit. Visit 5 corresponds with the infant being 7 weeks old - chronological age. If the saltatory decline was due to maturational influence we would have expected to obtain this sharp decline at visit 8, i.e. when the infant would be 4 weeks of age when age is corrected for prematurity. It would seem that the normal occurrence for the infant of failure to grasp any object reached for - due to Phase I reaching - results in grasping being greatly reduced by visit 5 in this subject in the same way as the 4 to 5 week old full-term infant. These two results of reaching and grasping point out that no simple adoption of a compromise between nativism and empiricism at either extreme is feasible. Maturation is occurring but while it is occurring environmental support is necessary and serving to re-direct further maturation.

On the twelfth visit, hand regard was observed while wearing the guide. The infant would typically wave his hand in the field of the guide and then track its movement. Also in this session, as with <u>KB</u>, the short-range guide was substituted with the same response occurring. Reaching correct as to direction but incorrect as to distance was produced.

After this, contact with this subject was lost, later to be re-established at 7 months of age. This produced the disadvantage of losing one subject out of the longitudinal study; however, it also gave us one major advantage. The previous subject, KB, after moving away had been seen only infrequently. This subject, on return, was seen once weekly as before. Therefore we could investigate more thoroughly what effect this long period of absence (five months) had on the effectiveness of use of the guide. There might have been "savings" in use, for instance. It was also thought that it might indicate what might happen with blind infants who were interrupted in their use of the guide. Such an interruption would not be uncommon. Fine (1979) points out that 50 per cent to 60 per cent of congenitally blind infants have additional handicaps. These handicaps may often lead to periods of hospitalisation which might mean loss of use of the guide. If use could be re-established with large "savings", then this would clearly be beneficial to the blind infant.

On the first visit at 7 months, attempts were made to establish reaching. Initially, this was tested with the infant sitting in a standard infant chair. This was unsuccessful in that the infant became distressed. The infant was then seated on his mother's knee. Again attempts to elicit reaching resulted in failure. This was repeated for several weeks with no reaching being recorded on any of these visits. Ten minute sessions of attempts to elicit tracking were initiated with the object moving at speeds from 1 cm/sec to 5 cm/sec. No appropriate responses were obtained, nor indeed were any head movements shown. It was thought possible, on the same argument as was presented in the last chapter, that although there were no reaching responses, the infant might still have been picking up some higher-order information from the signal. Time spent fixating the appropriate sector was therefore looked at. It was found that this infant, over the period of 7 to 9 mo months, fixated the sector containing the object an average of only 30 per cent of the time. This is not significantly different from the results obtained with the cross-sectional subjects of this age and shows no improvement over these subjects. Attempts at obtaining placing responses were begun at 9 months. When carried out in the light, the response could be obtained but only with difficulty. No such response was obtained in the dark, with or without the guide.

At 50 weeks of age, on MM's last two visits to the lab, the first indications of Sonicguide-specific response were obtained. In all sessions since the age of 44 weeks, the infant had been seated on his mother's knee at a large table. Objedts were placed on the table at various positions. For 6 weeks no response was obtained. In the last two visits, some use of the guide was observed however. The experimenter moved soundlessly into and out of the field.

MM smiled and reached for E. Secondly, a 100 mm^2 wooden block was placed on the table in the midline, 0.5 metre from the subject. He then stilled, turned and fixated the object then explored the edges with the guide. He then reached and touched the object, with grasping being tactilely elicited. These responses occurred on both occasions but were the only ones observed which used the properties of the guide.

Subject ES: Initially, reaching was again ballistic with frequency of reaching and grasping declining after 4 weeks, although some successful reaching was obtained on every visit up to 10 weeks. From this age up to 15 weeks, three separate controls were run to determine whether use was continuing on a perceptual basis.

Control Condition 1: At 10 and 12 weeks, the infant, while wearing the guide, was given no object to reach for. No reaching at all was observed, although he did make parallax head movements which seemed to suggest searching - this is confirmed below. This condition lasted for 5 minutes. Then the object was presented for 5 minutes in one of the standard positions. Two successful ballistic reaches were obtained.

Control Condition 2: At 11, 13 and 15 weeks, the control involving the altered range of sonicguide was carried out. This resulted in the previously described "perceptual" index of use, with the subject missreaching in depth.

Control Condition 3: This control was run at 12 and 14 weeks. In this case the usual stimulus object was presented to the infant, but at twice the distance normally presented. Reaching ceased, although the infant spent 73 per cent of the time fixating the appropriate sector.

The object was then moved laterally at varying speeds between 1 cm/sec and 5 cm/sec. Appropriate tracking was obtained up to 3 cm/sec but not beyond. Hand or fist regard was observed at 15 weeks. At 18 weeks, sonically-controlled reaching akin to visually controlled reaching was observed. After this reaching died out altogether for several months. However the parallax head movements described previously were still observed. That they appeared to indicate true searching was evidenced by the observation that these movements stopped at the object. At this point, they reduced in magnitude with the infant engaging in edge exploration. While only the 5 to 6 month old infants demonstrated this in the cross-sectional study, ES demonstrated the response up till 8 months of age, with an average of 70 per cent of the time being spent in fixating the appropriate sector.

At 9 months, placing tests were begun. These consisted, for this infant, and the others to be reported, of the following: Placing to two surfaces in three randomly assigned conditions. These conditions were A: light, B: dark without guide and C: dark with guide. One surface was a polystyrene block laid on the floor (to avoid any possible accidents). The infant was first brought to this surface to determine when visually-elicited placing had emerged. Once it had emerged, the other conditions were run. The second surface was a table edge parallel to the floor, and 0.75 metre above it. The infant was brought to this on a hit and a miss path at varying rates of approach. (In Conditions B and C, E_2 monitored approach on the remote television screen.) Ten trials of each were run. The results obtained with this infant can be seen in Table 5.4.

Table 5.4: Number of placing responses with Subject ES in three conditions of testing

CONDITION	Week Number 1 Surface Floor	Edge H	Edge M	2 Surface Floor	Edge H	Edge M	3 Surface Floor	Edge H	Edge M	4 Surface Floor	Edge H	Edge M*
A	10	7	-	10	8	-	10	10	-	10	9	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C	4	2	-	3	1	-	3	-	-	2	-	-

* H = Hit M = Miss

From Table 5.4 we see that, as expected, performance in the light is optimum, with no placing responses being shown when the infant is on a miss-path. That the response requires distal spatial information, and is not proprioceptive, is shown by the results of Condition B, where there were no placing responses shown. In Condition C, we observe that the nature of the distal spatial information can be amodal, with sonically-elicited placing being obtained. That the response is not operant in this condition is shown by there being no improvement in later weeks in the response; indeed there is, if anything, a decline in sonically-elicited placing over the sessions. There is also a suggestion of pick-up with the guide of difference between edge on a hit path and edge on a miss path; no placing responses were produced on the miss-path trials. The significance of this sensitivity is discussed later (see page 256). After the fourth session of placing tests, sonically-elicited placing dropped out of the infant's behavioural repertoire.

Locomotion tests were initiated at 11 months. This involved observing crawling and creeping under the three usual conditions. Crawling was observed in the light and sustained for three weeks. It was not observed in the dark, with or without the guide. By 12 months, when this subject was last seen, independent walking had not yet emerged and so could not be tested under Sonicguide conditions.

<u>Subject SK</u>: With this subject, reaching was again ballistic at first with the same pattern emerging as with Subject <u>MM</u>. (It will be recalled that <u>SK</u> was born 4 weeks premature.) With this subject, however, on week 2, anticipatory hand shaping was observed in two reaches ending in successful grasps of the object. Such hand shaping has been observed in neonates in the light (Bower, 1979 a) but has never been reported with Sonicguide users of any age, unless in reaching

to an already familiar object presented repeatedly in the same position. In this case the object was unfamiliar, and the hand shaping was obtained on the first two reaches which ended in contact with the object. At 6 weeks of age, the object was presented alternately on the right and left four times (R - L - R -L). Appropriate alteration of reaching to the correct sector was obtained on each occasion. On each of these occasions, after the object had stopped moving, the infant slowly moved her head to the object's new position. Fist or hand regard emerged at 12 weeks chronological age (8 weeks of age if corrected for prematurity). On the next three visits, no reaching was observed although fist regard was obtained on two of these occasions. At 16 weeks, Phase I reaching re-emerged and was replaced by Phase II sonically-directed reaching two weeks later. Change of object position resulted, on the first of these occasions, in a reversal to Phase I reaching; on the second occasion the new position was found with a Phase II reach. After this, guide reaching dropped out completely. Indeed it was extremely difficult to obtain reaching under visible conditions either.

From 5 to 9 months, the infant spent between 80 to 90 per cent of the time fixating the correct sector. If the object moved, she followed it. Presentation of the object at different distances resulted in correct tracking, although there was no further reaching. The search and fixation patterns described previously were also observed. Placing responses were not obtained with the guide, with it also being difficult to obtain them in the light. Typically, on these occasions, SK would hold her hands rigidly at her sides.

The next indication of use of the guide was at 10 months when the child was seated at a table and a variety of objects placed in front of her. She found one object - an abacus - very interesting under conditions of vision. On this occasion, under guide conditions, the abacus was presented soundlessly in the field of the guide. She immediately smiled and reached out with both hands, grasping the sides of the object. She then brought the abacus to her mouth and played with the beads on it. The guide then slipped to the left side of her head, resulting in the object being perceived by the infant as being to the right of the midline. She then reached to this point, altering her behaviour in a way akin to that seen with displacing prisms. No after-effects were obtained when the guide was re-positioned, unlike the after-effects seen with prisms. This was probably due to the fact that only one reach had been made while the guide had slipped out of position.

Up to the age of 12 months, when last seen, independent locomotion was not obtained - neither creeping, crawling nor walking. It was therefore impossible to test these behaviours under guide conditions.

Subject RG: With this infant, ballistic reaching did not show the same pattern of decline as in the other long-term infants. RG continued to reach at a high frequency after 4 weeks of age. Grasping also did not show a sharp decline after the neonate period. There was, however, a sharp contrast in behaviour between light and guide conditions. On testing up to the age of 17 weeks, there were only two occasions on which reaching with the guide was not obtained. During this phase, reaching in the light was investigated at 6, 9, 12 and 15 weeks. This infant showed few reaches in this condition on any visit, a result in keeping with the results obtained with the cross-sectional infants in both light and guide conditions. At 12 weeks hand regard was observed in both sonic and light conditions. Tracking of the laterally moving stimulus was observed at 6, 12 and 15 weeks. At 12 weeks, the short-range guide was substituted and the object returned to the same position as it had been with the long-range guide. The infant mis-reached in depth with her left hand and then gave a flurry of reaches with her left hand until contact was re-established. After four successful reaches, the long-range guide was again replaced on her head, and the infant again mis-reached, a further confirmation of perceptual pick-up of the information provided by the guide.

At 17 weeks, Phase II reaching with the guide emerged. On this visit the first evidence of anticipatory hand shaping was observed. As this occurred after three successful reaches to the object, it is not clear whether the shaping was sonically elicited or determined by previous contact with the object. Reaching with the guide dropped sharply after this. However, at 24 weeks, after obtaining three Phase II reaches, the short-range guide was substituted. The characteristic error pattern was obtained but this time with a Phase II reach which was corrected within the reach, in a way similar to that of Phase II infants when wearing prisms. (McDonnell and Abraham, 1979). Radially directed tracking was obtained at 20, 24 and 30 weeks. At 7 months, reaching dropped out in the guide condition. Appropriate fixation was still obtained for a further four weeks. Search and fixation measures while the stimulus was present were compared with measures obtained with no stimulus. Search behaviour continued in the absence of the object. On these occasions, however, the infant would typically lean over and fixate the floor, with little or no fixations of the sector where the duck had previously been. Fixations to this sector decreased from 77 per cent with stimulus to 33 per cent without stimulus.

At 8 months, the infant became distressed when put in the testing situation. This was apparently due, not to the signals from the guide, but to being in the dark. This response occurred for a further four weeks of testing.

At 9 months, placing tests were commenced. The results are shown in Table 5.5.

Table 5.5: Results of placing tests with Subject RG

CONDITION	Week Number 1 Surface Floor	Edge H	Edge M	2 Surface Floor	Edge H	Edge M	3 Surface Floor	Edge H	Edge M	4 Surface Floor	Edge H	Edge M
A	10	6	1	10	10	-	10	9	-	10	10	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C	6	3	-	4	1	-	-	-	-	-	-	-

The same pattern of placing behaviour emerges as with ES. That it is not an operant response in the guide condition can be seen by the fact that, while initially high, it drops out after the second successful session.

At 41 weeks to 46 weeks, crawling was recorded. On the first occasion, the infant would crawl to her mother while wearing the guide. When objects were soundlessly placed in front of her, she would stop before touching them but make no attempt to go round them. On these occasions, she would become distressed. No further successful attempts at crawling while wearing the guide were recorded. Independent walking had not commenced by the last visit, and could not therefore be tested under guide conditions.

Subject AH: This subject wore the guide on a twice-weekly basis. Phase I reaching declined in the same way as in all subjects other than RG, with a gradual decline in frequency from 4 to 12 weeks. (See Table 5.6 - in this case, because the subject visited twice per week, the number of reaches recorded under each Week Number refers to a mean of the scores obtained on the two visits for that week.)

Table 5.6: Frequency of reaching and grasping with Subject AH

	Week Number									
	1	2	3	4	5	6	7	8	9	10
Reaching	11	9	6	5	5	4	4	3	4	-
Grasping	8	7	4	3	4	2	3	3	3	-

The pattern seen in all longitudinal infants other than RG of a decline in reaches ending in successful grasps was not repeated in AH. Like RG, AH, although showing a decline in reaching, continued to produce reaching which ended in grasping, the number of grasps being almost as high as the number of arm extensions. It appears thattwice-weekly visits were sufficient to maintain the success if not the frequency of earlier reaching.

It was thought possible that when wearing the guide, the infant may simply have learned that there was an object in one of two places (right or left of midline) when he was lying on the bed. To test this several control conditions, described previously, were carried out.

1. Short-range guide; This control was tried when the infant was 6, 8, 10 and 12 weeks of age. On three of these

occasions, the infant demonstrated the characteristic mis-reach, and on two of these three occasions cried after failing to contact the object. On the third occasion (8 weeks), the short-range guide was switched back to the long-range guide (after mis-reaching with the short-range). No further reaching was obtained. At 12 weeks, no reaching was obtained with either range of guide.

2. <u>No object in field of guide</u>: This control condition was carried out at 9 weeks of age. No reaches to either standard position were obtained in the absence of an object in the field of the guide.

3. <u>Guide switched off</u>; On one visit, during week 6 (i.e. when he was 8 weeks of age), <u>AH</u> lay wearing the guide but without it switched on. The stimulus object was placed in one of the standard positions. The infant lay motionless and after 3 minutes seemed to have fallen asleep. The guide was then switched on, and three reaches to the object were observed (one ending in a grasp).

The responses (or non-response) produced in all three of these control conditions therefore refute the possibility that the infant had, over two visits per week, come to associate sitting in the dark (with the guide switched on or off) with finding an object in one of two positions.

At 12 weeks, sonically-elicited fist or hand regard was obtained. <u>AH</u> held his left hand in the field of the guide in the midline and alternately opened and closed it. Then he waved it in and out of the field. This was followed by his bringing his closed hand to and from the guide at forehead height. At this time, tracking tasks were begun. Results showed immediate transfer, with the infant "following" the object with appropriate head movements each time the track of the object was changed. Tracking was obtained with the object moving at rates up to 5 cm/sec. Beyond this speed, the infant made large parallax head movements as if trying to find the object. This latter behaviour was observed at 14 weeks of age. No reaching was obtained during this period.

At 16 weeks, sonically-directed reaching emerged, with both ipsilateral and contralateral reaches ending in grasps occurring. At 17 weeks, the infant engaged in hand regard of both hands. This consisted of the hands being held about 10 cm apart and the infant making accurate lateral head movements to fixate first one hand and then the other. This behaviour suggests that the argument of Kay that any response to multiple objects is psychophysically impossible is wrong. He argued that presentation of two separate objects results in perception of a single object midway between the two (see Appendix II). This would only be true if no head movements were made, however, as Bower (1977 b) has highlighted. That infants can and do make such head movements to discover multiple objects is clear from the results obtained with <u>AH</u>.

At 19 weeks, the object was moved laterally in an attempt to investigate tracking again. The infant not only tracked the object, but made a contralateral reach to intercept the object on its path of movement. This response was repeated on the next visit. Sonically directed reaching progressively decreased in frequency over the next three weeks. At 23 weeks of age, it dropped out of the infant's behavioural repertory. Auditory-manual co-ordination could not be obtained either. That the infant was still using the signals as information was evidenced by the measure of sector fixation described previously. The infant would typically make large head movements until the object was in the field of the guide. At this point, the head movements would decrease in magnitude and the infant would make very small head movements while exploring the edge of the stimulus. No reaching was observed during this phase. At 30 weeks, this behaviour also ceased. For the next four weeks (8 visits), objects of different sizes, textures and shapes were presented to him; as well as this, presentation of multiple objects was also tried. Attempts were made to establish social interaction games. In short, every technique that could be thought of was initiated to try to obtain an index of guide use. None of these was successful, and it appeared that guide use had dropped out completely.

At 35 weeks, placing to a visible surface emerged. Placing tests with the sonicguide were therefore initiated. The procedure used was the same as that described for other longitudinal subjects. Results of these tests can be seen in Table 5.7. In this case, visits 1 to 4 were spread over two weeks.

Table 5.7: Results of placing tests with Subject AH

CONDITION	Visit Number 1			Visit Number 2			Visit Number 3			Visit Number 4		
	Surface			Surface			Surface			Surface		
	Floor	Edge H	Edge M	Floor	Edge H	Edge M	Floor	Edge H	Edge M	Floor	Edge H	Edge M
A	10	9	-	10	10	-	10	10	-	10	10	-
B	-	-	-	-	-	-	-	-	-	-	-	-
C	7	6	-	6	4	-	2	1	-	1	-	-

As can be seen, sonically specified placing was easily elicited in its emergent phase yet, despite the opportunity for learning, it was not sustained and dropped out very rapidly. Within two weeks, its occurrence with the guide had dropped out completely.

At 36 weeks, crawling emerged with this infant. The behaviour was tested in a variety of situations under the three conditions of light, dark without guide, and dark with guide. Firstly, the infant was called by his mother from a position 2 metres away. In the light (A) and guide (C) conditions, he immediately approached his mother, stopping before bumping into her, and putting out his arms to be lifted up by her. Without the guide, (B), he would not move from where he was sitting and soon became distressed. Secondly, the lights were extinguished while the infant was already crawling and a polystyrene board 2 m x 0.5 m was placed soundlessly a short distance in front of him. Both mother and experimenter remained silent during this period. If wearing the guide, the infant continued to crawl but stopped at the obstacle. If not wearing the guide, however, AH stopped moving as soon as the lights were extinguished. Thirdly, the same board was placed in front of the mother (once the lights were extinguished and she had called on the baby to approach her). In B, AH headed straight for his mother, oblivious to the obstacle; in C, he crawled around the obstacle without touching it and arrived at his mother. In both bases, there was no crying or any other sign of distress.

Lastly, an obstacle course was constructed for AH to crawl through. Fig. 5.1 shows the layout of the course. AH was placed at a random point in the course within the field of the camera. The obstacles were placed in their positions after the lights had been extinguished. The aperture between the polystyrene blocks, was one and a half times the width of the infant's body. On three consecutive visits, while under guide conditions, this course was successfully navigated; AH avoided all the obstacles, going through the aperture and arriving at his mother. Again, he seemed quite happy while doing so. On the first and second visit, he stopped at the block in front of the mother, searched the floor by head movements, and picked up the toy from the floor (a small rubber toy, 10 cm long by 5 cm wide). He then carried it to the mother. Not surprisingly, under

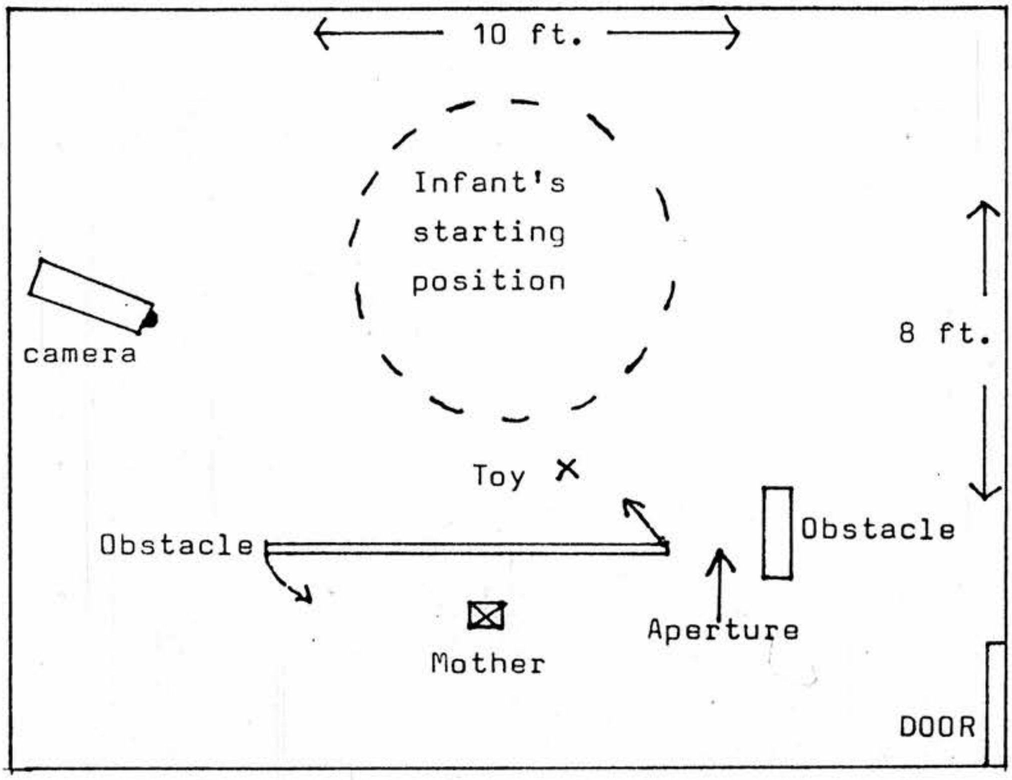


Fig 5.1: Layout of obstacle course used for locomotion tests with Subject AH

Condition B, the infant did one of two things in this task. He either would not move from his starting position, or else, if he did move, he went straight to the mother, crashing through the polystyrene barrier. Obstacles and apertures therefore presented no problems to this infant while wearing the guide. In addition he could pick up a small toy from the background signal of the floor. (One observer thought that the infant was performing in the light until the experimenter appeared in the field of the camera, groping unsuccessfully for the toy which the infant had already picked up.) At 46 weeks this behaviour dropped out.

Object permanence tasks were then begun at a table surface. The infant would select a favourite toy from a group of three objects but would not engage in object permanence tasks. At this time, he would engage in social interaction games and would smile when the experimenter came into the field of the guide, thereafter following his movement with the guide.

At 50 weeks, independent walking emerged. AH was again happy to walk around with the guide on, stopping before he touched obstacles, and walking around large obstacles to get to his (silent) mother. With the guide switched off, he remained motionless in the dark. However, with the guide on, he would not focus downward, which resulted in his tripping over toys on several occasions. At 54 weeks, testing of this subject was terminated.

DISCUSSION

The results obtained with the long-term users of the guide are by no means as clear-cut as those obtained with the cross-sectional subjects. There is a great deal of individual variation in use, due in some cases to unforeseen circumstances such as infants dropping out of the sample for extended periods. However, several patterns do emerge. Firstly, the decline in perceptual usage seen at 5 to 6 months of age in the cross-sectional study was not obtained in this study. All but one of the subjects in this study continued to show perceptual usage up to the end of the experiment. The emergence of new behaviours and immediate response transfer seen with young infants was again in evidence with these subjects, but this time continuing up to 12 months. The exception to this was KB. His weekly visits were terminated and then after a gap of two months, changed to once every two months. Guide use appeared to have been lost by then. It seemed that, despite at first being able to use the guide perceptually, the information provided thereafter was not frequent enough to allow continuing perceptual usage. It is not certain whether this would also have happened with a blind infant. KB had an alternative, and much more functional, sensory system to fall back on - vision. It is possible that a blind infant, given the opportunity to use the guide up to 5 months of age, but with it then becoming unavailable, might be able to develop spatial concepts later, capitalising on the early input of spatial information through the Sonicguide. Work done with subjects not blinded until after 6 months of age show that vision up to this period can certainly lay down structures for later emergence of spatial concepts (Bower, 1979 a). While there was no evidence of later perceptual usage in KB, the tasks required of KB in the later infrequent tasks did not allow for operant use of the guide. It may be that early perceptual use followed by a long period of absence of guide input, may facilitate later operant use.

MM went through a similar period where the guide was not worn after an initial period of perceptual use. In his case, the gap lasted for four months. Despite weekly sessions being resumed after this long gap, no effective use of the guide was obtained until the infant was 12 months of age, at which point the guide was again used "perceptually". This would suggest that early use of the information up to 5 months did serve to lay down later sensitivity to that information. This conforms to one account of differentiation - where differentiation occurs without loss. That account does not, however, explain the infant showing no use of the guide in the period between 3 and 7 months, when weekly visits were resumed, and 12 months, when use again picked up.

There is one possible explanation for this period of non-use which would tie in with other observations made of this infant during this same period. Not only was there no guide use but very few new responses emerged in the light during this time. It was difficult to obtain visually-elicited placing. Independent locomotion did not emerge. It was difficult even to obtain reaching to a visible object. The child generally seemed to be very passive, an observation shared by the second experimenter. It is possible that the responses observed with the sonicguide at 12 months were due to the infant finding this to be the first task of any interest he had been asked to perform. (It will be recalled that the first responses occurred at 50 weeks with the experimenter playing a peek-a-boo game with him.) If so, then this would suggest that passivity may be a generalised trait, affecting all behaviours. It also points to the possibility that the same processes are occurring in vision and with the guide.

From the results of this and the preceding chapters several conclusions can now be drawn. These conclusions support some theoretical stances and discount others. Firstly, it has been established that the guide can be used by some subjects of all ages. The results of Chapters 2, 3 and 4 testify to this. Secondly, age differences in effectiveness of use were found. This was found for both blind and sighted samples of subjects. The cut-off for amodal use was earlier (at 5 to 6 months) for the sighted than for the blind (8 to 9 months) infants. One possible explanation for this observed difference is that the blind continue to use amodal information for longer.

The present chapter has also gone some way towards providing an explanation for these age differences. We can discount any explanation which is based on maturational factors. Such a view would, for instance, have to postulate that the same responses would appear in both cross-sectional and longitudinal sighted subjects. The difference in results given in this and the preceding chapter show that this was not the case. The drop in performance with the guide obtained with the cross-sectionals at 5 to 6 months did not occur with the longitudinals. AH for instance, showed sensitivity to quite complex information in his use of sonic information in the placing tasks at 9 months. In the drop to the table edge, a signal would be coming both from the floor and from the edge; AH seemed able to separate the two signals accurately.

As with explanations based on maturation, we can also discount explanations based on standard theories of learning. This type of account would argue that frequency and duration of exposure would be all important. The results should, therefore, have demonstrated that, provided these factors are equivalent, then equivalent use of the guide should be obtained. Additionally, this view cannot account for new behaviours emerging. Even in the case of "normal" development (that is, without the sonicguide), learning theories find the occurrence of new behaviours an embarrassment. In the artificial world of the guide, new behaviours still emerged. No current learning theory could explain this.

Similarly we can discount the type of differentiation account offered by Gibson and Spelke (1981) as a possible explanation. This too is an associationist account, involving association of higher-order invariants. It would predict an increase in use with increasing exposure. It cannot explain the qualitative and quantitative difference in use which occur, in the direction of decreasing ability to use the guide with increasing age of first exposure.

Clearly, the explanation lies in some experimential or environmental factor which has to do with age of first exposure to the guide. Strict criteria were demanded for the designation of what has been termed use. These were, it will be recalled from Chapters 2 and 3, immediate transfer of response success and the emergence of new behaviours. The former criterion was tested in several ways, for instance in changing the range of the sonicguide. This criterion of use and the latter criterion of emergence of behaviours were both fulfilled by the subjects in the studies reported in the present chapter. What is it then that is occurring in early experience which allows for perceptual use of the guide? Three possible explanations remain. These will be considered only briefly here, as they are detailed more fully in the final chapter.

The first is in the differentiation account offered by Werner (1948). This postulates a biological process going from global to articulated to reintegrated. His account is one of differentiation occurring with loss. This would fit in with the results of the cross-sectional sighted subjects. In their case, with differentiation occurring at 5 to 6 months, there is then no possibility of supra-modal linkages. Information becomes modality-specific. This is not, however, consistent with the results of the longitudinal subjects. If the process of differentiation were truly biologically determined, then the same qualitative difference in use should have occurred with these subjects. This was not the case.

The account of differentiation in development offered by Bower (1979 a, b, c, d) would seem to be consistent with the results reported here. His account argues that differentiation occurs without loss. The pick-up of modality-specific information, after differentiation has occurred, is added on to the pick-up of amodal information present in the undifferentiated organism. In terms of the evidence presented here, however, this theory would appear to have more descriptive than explanatory value. The implications of the results presented here for Bower's theory will be discussed in the final chapter of this thesis.

The account offered by Piaget would appear to be the one most consistent with the results presented so far. For Piaget, the emergence of new behaviours merely requires perceptual information to support and sustain these behaviours. Action is primary, with perception merely serving an alimentary role. The stimulus necessary for the development of an action sequence like reaching could therefore be in the nature of light or through the sonicguide. This account could therefore explain the results obtained with the cross-sectional and longitudinal blind subjects. If the perceptual aliment (the

Sonicguide) is not provided during the emergent phase of the behaviour, then the behaviour will not be sustained. This was seen, for instance with SN. This account would seem also to explain the difference between the cross-sectional and longitudinal sighted subjects. If in the search task, the sonic information is not provided during the phase when the action sequence is being established, then that action sequence will already have been established with vision. This is what seemed to have occurred with the cross-sectional sighted subjects. With the longitudinals emergent behaviours have either light or sonic field to seize on. Consequently during the emergent phase of a behaviour, the sonicguide can be used.

All of these latter three theories would, at this point, seem to fit to some degree with the results obtained in this thesis. Each will be dealt with as a possible explanation in greater depth in the final chapter. Firstly, however, the next chapter will consider more closely how these infants were using the information provided by the signals of the guide.

Before turning to a discussion of how the guide is being used, one final point should be made. This relates to one of the main concerns of developmental studies. Since such studies were begun, discussion has centred around the origin of behaviours. On the one hand were the nativists (e.g. Gesell, 1929) who advocated that new behaviours were solely maturationally determined. At the other extreme were the empiricists who advocated that environmental input was the sole determinant of the origins of behaviour. Fraiberg's (1977) work with the blind typifies this approach. Without the environmental input of vision, certain behaviours either do not emerge or else will emerge in a different form.

The present study is the first ever study to demonstrate that an artificial environmental stimulus input can lead to the emergence of new behaviours. This chapter has shown that the information provided by the sonicguide can programme the development of these new behaviours. It should be noted though, that, even with this degree of control over the amount of input the infant was receiving, assignation of the origin of behaviours was difficult. The experimenter controlled the information by the turn of a dial, so that he had complete control over the information provided within each experimental setting, with there being no possibility of additional similar input outside of this setting.

CHAPTER 6 - STIMULUS PARAMETERS OF THE SONICGUIDE

INTRODUCTION:

The results presented so far have pointed to there being very rapid use of the guide in infants under about 30 weeks of age. This type of use has allowed both sighted and blind infants to develop behaviours not normally obtained when no vision is available. The rapidity of use was striking, especially when compared with the performance of adult users, many of whom could make no use of the guide after many hours of training or learning (in the case of the blind) and, in the case of sighted adults, showed no immediate response to guide use. Adopting the criteria of rapid use - immediate transfer of success and the emergence of new behaviours - argued for previously, we see that this result appears to consistently emerge in this set of studies and previous studies using the guide (Bower, 1977 a; Bower, Watson and Umansky, 1979). Bower has suggested that data like these present a serious challenge to current theories of perceptual development. At least since the publication of E.J. Gibson's work (Gibson, 1969) most theorists would accept that some perceptual abilities are innate and unlearned. The strongest and most convincing criterion for the innateness of a particular ability is its presence in very young infants, infants too young and inexperienced to have learned the ability through learning. This argument assumes that evolution has acted on the genes in order to build the necessary structure into the organism. This argument also assumes that just as humans have evolved structures to breathe air so they have evolved structures to pick up the layout of the visual world; the layout of the visual world has been as constant throughout our evolution as has the composition of the air.

However, the results of the sonicguide work directly contradict this view, The infants in the studies presented here who showed "perceptual" usage have all been, in terms of exposure to and experience with the guide, "younger" than any of the subjects in experiments purporting to demonstrate innateness (except for the study by Wertheimer, 1961). At first sight there is no possible evolutionary basis for use of the device, nor indeed for any device of this kind. Sonicguides have not been available throughout our evolution. A theory postulating differentiation in perceptual development would, however, argue for the innate presence of "perceptual" structures, not registering sensory-specific information but registering amodal or higher-order information. Evolution would, in that case, have acted on the genes to build structures which register this type of information, information with such higher-order properties as distance change, size, direction and texture. An explanation for the rapidity of use by the young infant may therefore be in terms of a theory of differentiation in development. Differentiation is, as has already been shown, an epigenetic process resulting in developmental change (Bower, 1979 a). This argument then suggests that, with young infants, the information pick-up is truly "perceptual" rather than operant. It is with the older subject attempting to use the sonicguide that, on this account, we first encounter use of the guide as an operant signalling device. By this time, due to overlay of modality-specific information, that is input of a lower order, a laborious process of relearning is required for both blind and sighted guide users.

On this account, there are two different ways in which the guide, or any novel sensory input which preserves amodal characteristics, may be used. One is on the basis of the initial undifferentiated use shown by the young infant. The second adheres to standard known processes of learning, learning to associate a particular signal with a particular position, and learning that a slightly different signal represents a different position or size of object for example. However, there is a third possible means by which the young infant may be using the guide, which also accounts for him using it to much greater effect than the older infant, child or adult subject. This possibility rests on the argument that the young infant is <u>learning</u> to use the guide, but that the process of this learning is qualitatively different, much more rapid, than the processes of learning seen with the older subject.

The most important difference between this and the former, differentiation account, is that if learning is involved then the process would be reversible, while the processes of development are irreversible. The idea that early learning in the young infant of a species is qualitatively different from the learning involved later is not new in psychology. Hebb (1949) first suggested that the young of a species learns much more rapidly than an older member of the species. More recently, Papousek has shown that later learning may be facilitated by opportunities of early learning (Papousek, 1967) 1972; 1979). Papousek described this as the infant testing hypotheses about events in his environment. These infants were learning how to learn (Bower, 1979 a) i.e. learning in this case being more abstract than the learning of specific contingencies. Siqueland and Lipsitt (1966) have shown that the newborn can detect response-event contingencies, and can rapidly detect any changes in these contingencies. Hinde (1966), too, has argued that the young human may have special learning skills, although without attempting to specify what these skills may be. Indeed, Lipsitt has proposed that research should not adhere to

> "any particular mode of learning or any special theoretical model for the understanding of specific learning effects that may be induced in the immature organism."
>
> (Lipsitt, 1969)

By adopting a more "open" approach, he argues that many more possible lines of enquiry could be opened up (Lipsitt, 1972). He further suggests that the human neonate is as competent at learning as he ever will be, and

> "(that we) were impressed by the remarkable speed with which the newborns developed discrimination"
> (Lipsitt, 1972)

A major problem with a theory which argues for extremely rapid learning is that proponents of such a theory can argue that any ability is learned, with the learning having taken place in a microsecond. Such a possibility does not easily lend itself to experimentation when we consider "normal" stimulation from the environment. Whenever a new response is obtained, for instance, such a theory would state that the necessary contingency occurred at some time outside of the experimental situation. The sonicguide, as it is an entirely novel sensory input, offers a possibility for controlling the presentation of information about the environment to determine if the signals of the guide are associated with external events extremely rapidly.

The study to be reported in this chapter was intended to try to decide between the rapid learning option and the higher-order variable option. If the higher-order properties or form of the stimulation is what is being picked up, then any tampering with that form should inhibit rapidity of use. If, on the other hand, rapid learning is what is involved, then the form of stimulation should be irrelevant provided it is consistent over time i.e. bearing some consistent relationship with events in the world.

In this experiment perception of approach was investigated. Bower, Broughton and Moore (1970 a) first showed that young infants would make defensive responses to visually-specified approaching objects. As was reported in Chapter 2, the argument by Yonas et al (1977) that this was not a defensive response, but that the infant was merely following a rising contour, was refuted by Dunkeld and Bower (1980). They showed that young infants will withdraw their heads when presented with a visual display specifying approach but associated with a falling contour. The response to approaching object measured in their experiment was amount of head withdrawal. In the present experiment, the same paradigm of investigation was used. On this occasion, we are looking for sonically-elicited responses to approaching objects.

Infants wearing a sonicguide (as used in the studies described in previous chapters) were presented with an object moving to and from their faces in the midline. In one condition the guide signal was consonant with reality; that is to say as the object approached the baby, the guide presented its normal signal for approach, the ecologically valid time-change function shown in Fig. 1.9 (page 39). This condition will from now on be referred to as "Congruent" (i.e. information congruent with reality). In the other condition the guide signal was not consonant with reality, that is to say, as the object approached the infant, the guide gave a signal indicating withdrawal of an object, the inverse of the time-change function described above. This condition will from now on be termed "Non-congruent" (i.e. information was opposite to reality).

METHODOLOGY

Subjects: For this experiment sighted infants acted as subjects, being recruited through the normal channels as described previously (see Chapter 2). It was felt that this type of study could not be carried out with blind infants, it being considered unethical to present previously inaccessible information about the environment to these infants only to later disconfirm this information. None of the subjects involved had participated in Sonicguide studies before. Twenty subjects were in the original sample (10 male, 10 female), their ages ranging from four to twenty weeks. Six of the original subjects dropped out due mainly, it seemed, to the apparent intrusive nature of the experiment. As can be seen below, the apparatus used in this experiment was complex, some of the mothers appeared anxious at this, with their infant perhaps picking up this anxiety and becoming distressed.

Apparatus: The apparatus consisted of a cubic frame (2m x 2m x 2m) made from 2.5 cm Dexion Speedframe (see Fig. 6.1 overleaf). Two Unislide tracks, each 1 metre long, were connected to the top of the frame.

Track 1 was mounted horizontally and a 5 mm diameter, 30 cm long extruded brass rod projected downwards. Attached to the end of the rod was a polystyrene block 20 cm x 15 cm x 5 cm which moved along the track. The power for movement along the track was supplied by a Bodine motor. At one end of the track the Sonicguide was mounted on an aluminium frame which was free to rotate about its vertical axis. Therefore when the frame was in the centre of its axis, the Sonicguide signalled the object (the polystyrene block) to be in the midline. Any movement of the frame would therefore utilise the radial direction signal of the guide. For instance, a turn to the right would mean that the object would be signalled as being to the left of the guide; if the frame turned back to the left, this would indicate a recentralisation of the object. The object's movement along the track utilised the distance cue of the guide - as the object approached the frame which held the guide the pitch index lowered.

Track 2 was mounted so that it could swivel through an arc of 60°. A similar rod to that of Track 1 projected downwards. At the end of this rod a soft toy was attached - the fluffy duck used in the experiments described in the previous two chapters. The fluffy duck was of the same dimensions as the polystyrene block mounted on the rod attached to Track 1. The movement of this duck was also powered by a Bodine motor. At the end of this track a standard infant chair was positioned, set at an angle of 30° recline. This track was swivelled so that, at the end of its travel, the duck would tap the infant sitting on the chair on the nose.

The signal was transmitted from the guide to earpieces on a mounting on the baby's head. Extensions from the ear-

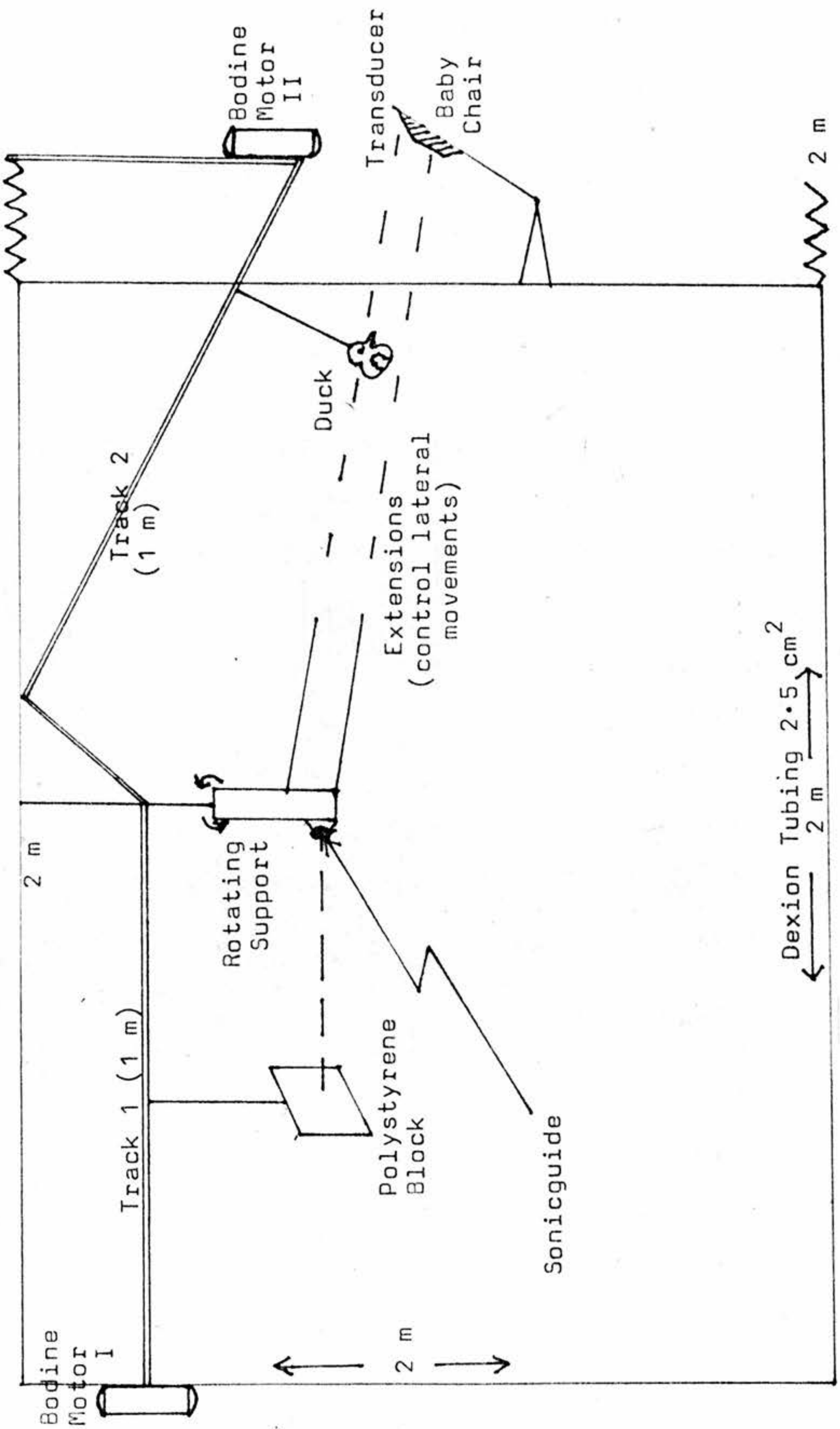


Fig. 6.1: Diagram of apparatus used

pieces to the frame on which the guide was mounted enabled lateral head movements to be converted to frame movements, and hence Sonicguide movements. This utilised the radial direction index of the guide.

By this means the two objects could be moved independently. In one case the object movement would be congruent, in that the object would approach and contact the guide and the duck would simultaneously approach and contact the infant. The speed of movement of both objects could be controlled and was set at 10 cm/sec, it therefore took 10 seconds for the objects to move from one end of the track they were on, to the other. In the second case the objects were moved non-congruently so that, for instance, the block approached the Sonicguide on Track 1 (the signal change produced being transmitted to the baby) while the duck on Track 2 receded from the infant. Similarly the speed of movement of both objects was set at 10 cm/sec with each full travel again taking 10 seconds.

Behind the infant's head a foam-padded head pressure transducer picked up any head retractions in response to the looming object (as indexed to the infant by the sonicguide). The transducer output was recorded through an F.M. tape transducer onto the audio channel of a Sony high-density videotape recorder. The changes in head pressure recorded were played back on a Tektronix 2000 oscilloscope.

The experiment was carried out in total darkness in a light-tight room (the same room as was used in the previous studies reported). Two 100 W infra-red lights (850 nm frequency) allowed filming to be carried out in the dark. These were mounted on the top of the Dexion frame and the light reflected off a back wall. Two infra-red sensitive cameras were connected to a V.T.R. and monitor via a Sync. generator. The V.T.R. monitor and generator were situated outside the experimental room. One camera recorded movement of the objects on both tracks along the whole of their lengths. The second camera recorded the infant's repponses to the moving objects. This, plus the head pressure output being recorded on the audio channel, allowed precise correlation of infant behaviour with the two displays.

Design: A repeated measures design was used, with each subject receiving both the Congruent and Non-congruent conditions. Half the infants received the Congruent condition first and half the Non-congruent first. In the Congruent condition, the first trial could either be contact/contact (i.e. duck approaches on Track 2, and object approaches sonicguide on Track 1) or non-contact/non-contact (i.e. duck recedes from the infant on Track 2 and object recedes from sonicguide on Track 1). In this condition the higher-order properties or the form of stimulation involving distance change are retained. If therefore these are the parameters of stimulation used by the infant, as suggested by differentiation theory, then we would expect the infant to show more head withdrawal in the contact/contact than the non-contact/non-contact presentation. This serves as a control for comparison with the second condition.

In the Non-congruent condition the first trial could either be contact/non-contact (i.e. duck approaches infant on Track 2, but object <u>recedes</u> from guide on Track 1), or non-contact/contact (i.e. duck recedes from infant on Track 2 but object <u>approaches</u> sonicguide on Track 1). In this condition therefore, the signals presented by the guide are consistent over time but do not conform to the abstract form of stimulation of an approaching object.

One of two predictions can then be made depending on which parameters of use the infant is working on. According to the form hypothesis, i.e. differentiation theory, we would expect the infant to show most head retraction in the non-contact/contact series of presentations. That is the duck is receding from the infant but the guide is specifying the higher-order property of approach. If, on the other hand, the rapid learning hypothesis is correct, we would expect the infant to show most head retraction in the opposite series of presentations - the contact/non-contact series. That is, the infant would have associated the signal over time of the guide as an object coming to collide with him, but the form of the signal of the guide would be the inverse of approach.

Each subject received six Congruent and six Non-congruent trials. The first trial received was randomised for each subject. There was no gap between trials with the motors being immediately switched in the opposite direction after the completion of each track run, i.e. each presentation. In changing from the Congruent to the Non-congruent condition, or vice-versa, two possible next presentations could be run e.g. changing from Congruent to Non-congruent the change trial could either be to contact/non-contact or to non-contact/contact. This change pattern was randomised so that half received one and half received the other pattern. At the point of change one motor was stopped and the other continued running until it reached the opposite end of the track, at which point the first motor was re-started and both were then run at the same speed.

Procedure: The infant was strapped into the reclining seat with supports for the arms to prevent any slumps in posture. One experimenter remained in the room to switch on the sonicguide and to control the movement of the objects. A second experimenter was outside the experimental room with the infant's mother, observing the infant's behaviour on the T.V. monitor. Once the infant was settled the lights were extinguished and the guide then switched on. There could therefore be no possibility of the infant obtaining any visual information of object movement along either of the tracks. The motors were then switched on and the objects moved soundlessly along the tracks at 10 cm/sec. Immediately the presentations of the first condition were completed, the presentations of the second were begun. Overall, the experiment lasted for approximately five minutes.

RESULTS

Difficulties arise in the selection of a response measure. Fig. 6.2(a) (see over) shows a typical recording obtained with a 4-week old infant. Absolute measures of head pressure would not be comparable, as initial head pressure recordings would vary with each infant. With variations in infant's head weight there would also be differences in initial head pressure. Any movement backward or forward has to be followed at some later time by a head movement in the opposite direction. In this study we are most interested in pressure recordings at time to contact, and in the infant's responses just prior to this time. Consequently, the interval chosen to look most closely at comprised the last three intervals (four squares) of the oscilloscope trace reading. This corresponded to a time-to-contact interval of 2.1 second to zero i.e. point of contact. The peak pressure at each of these points was recorded for each presentation. Prior to this, all peak points for each time interval on the oscilloscope were integrated for each subject in each trial. An example of this is seen in Fig. 6.2(b). This pressure reading shows for one subject the sum of trials for all contact/contact.

As it is change of head pressure over time we are interested in, the next step was to investigate what happens between Time Interval 1 and Time Interval 2; T.I. 2 and T.I. 3 and so on. To determine change, the angle of the line joining T.I.s was measured. From Fig. 6.2(b) we see

(a)

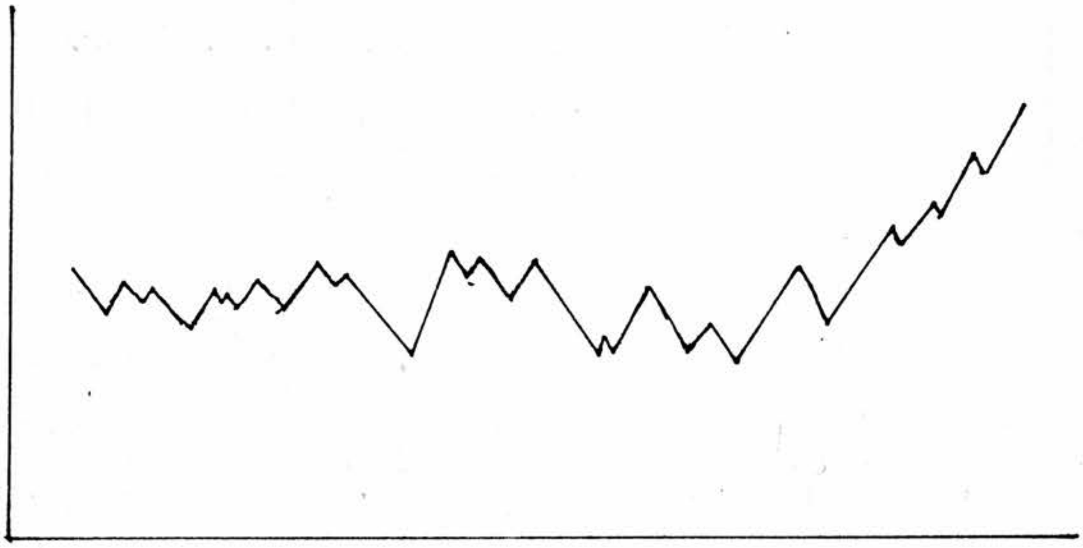


Fig. 6.2(a): Typical pressure recording for one subject

(b)

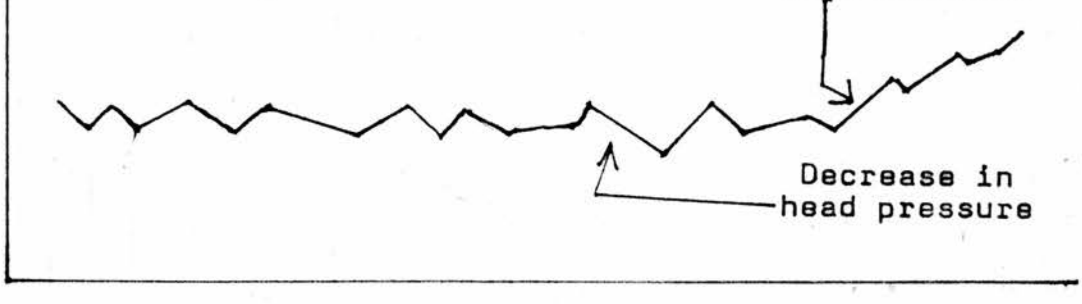


Fig. 6.2(b): Pressure reading summed for all trials of contact/contact for one subject.

that an angle of less than 90° indicates an <u>increase</u> in head pressure (response to approaching object). The closer the angle is to 0° the greater the change in increase of head pressure (i.e. pressure is greater over a shorter time). An angle of greater than 90° indicates a <u>decrease</u> in head pressure. This could vary from 90° to 180°. For each time interval these were then summed for all infants for each condition. Means were then calculated. Fig. 6.3 shows the integrated pressure changes up to the point of contact for each condition. The vertical dotted line represents 2.1 second before contact. As can be seen the amount of fluctuations up to this point cancel out to give an approximate straight line representing zero pressure change.

For the points we are most interested in, from 2.1 to 0 sec., we would expect for the Congruent condition that contact/contact would show an increase in head pressure. We would expect also that non-contact/non-contact would show a decrease in head pressure. From Fig. 6.4 we see that this hypothesis was supported.

In the three time intervals studied there was a continuous rise in pressure in the contact/contact presentations while as the object withdrew (non-contact/non-contact) the pressure reduced. These differences were then converted to Difference scores (Guilford, 1956) with the results obtained for the Congruent and Non-congruent conditions being represented in Figs 6.5(a) and (b) (see over). It is seen that the marked D score of the Congruent condition is not as marked in the Non-congruent condition. Correlated

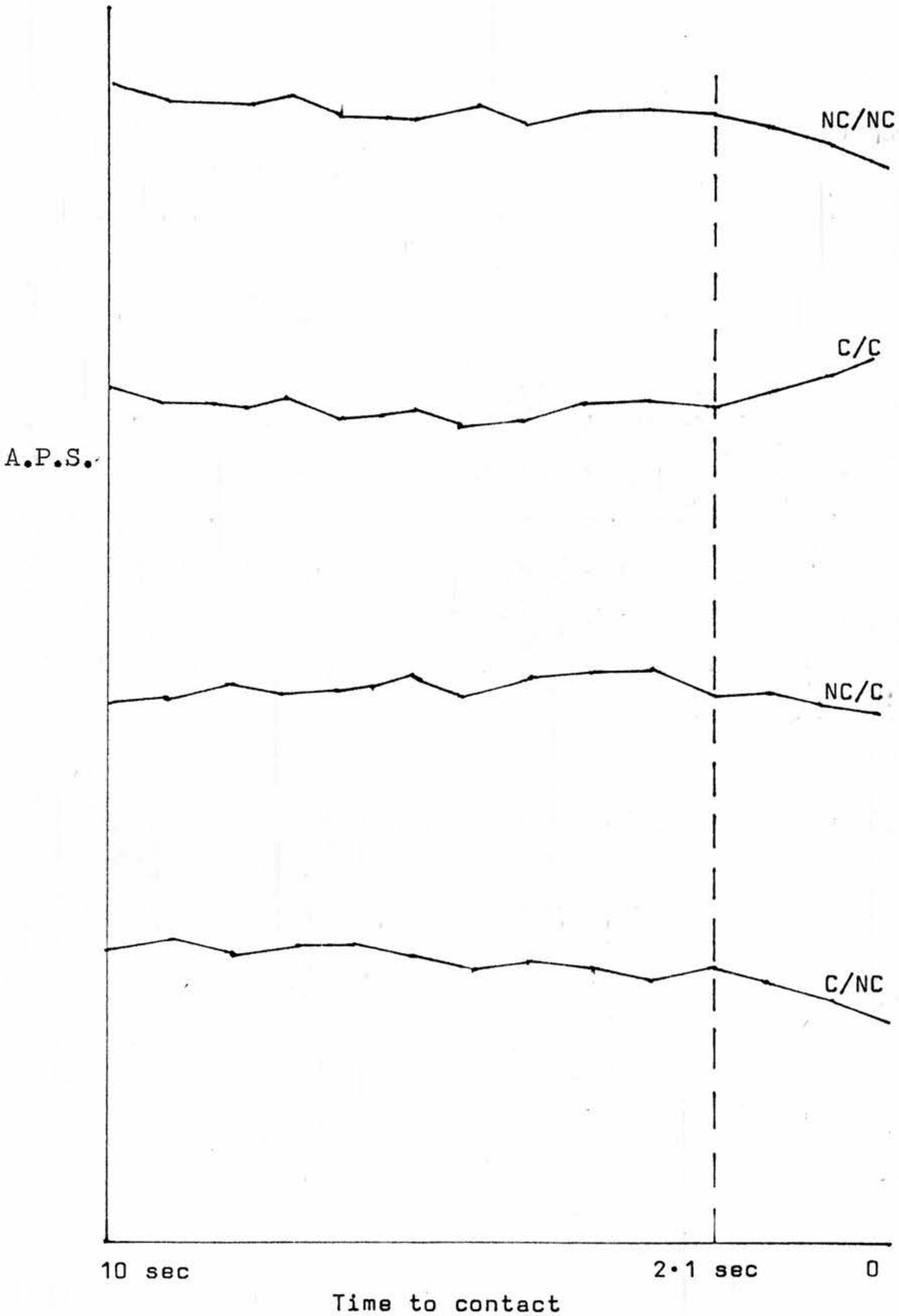


Fig. 6.3: Integrated pressure changes for all subjects up to the point of contact for each set of presentations (A.P.S refers to Analogue Pressure Signal)

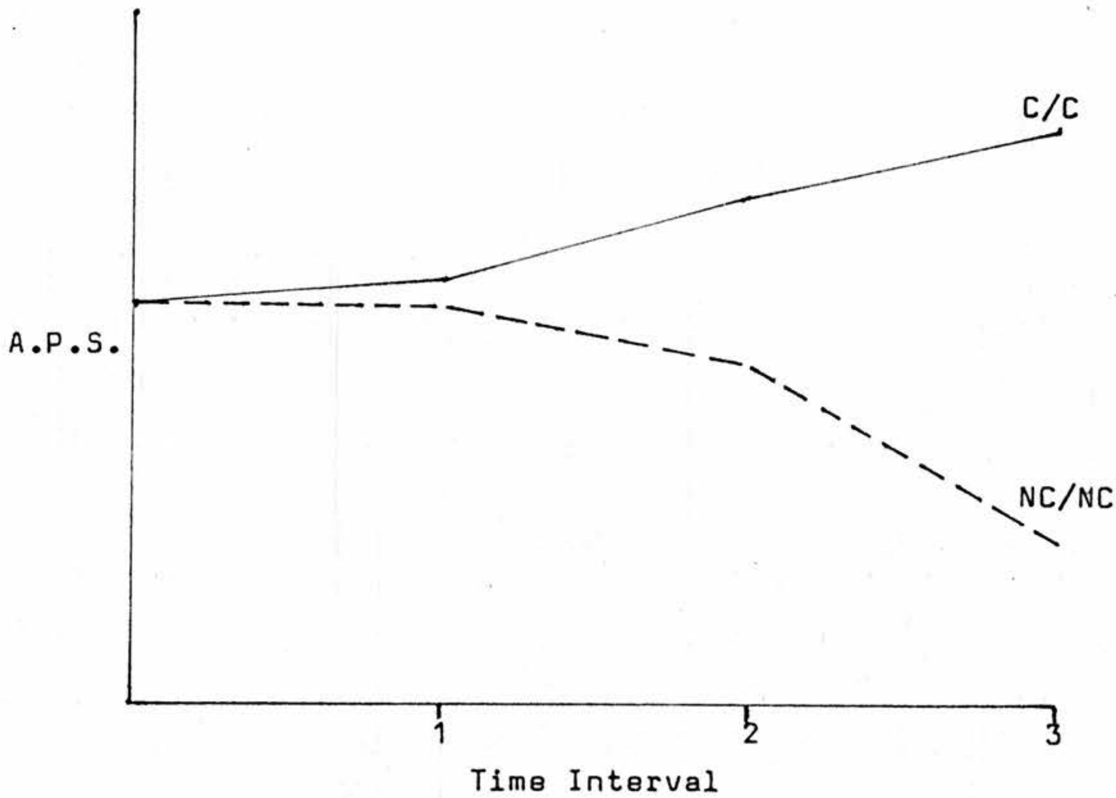


Fig. 6.4: Change in head pressure for interval 2.1 sec to 0 sec (point of contact)

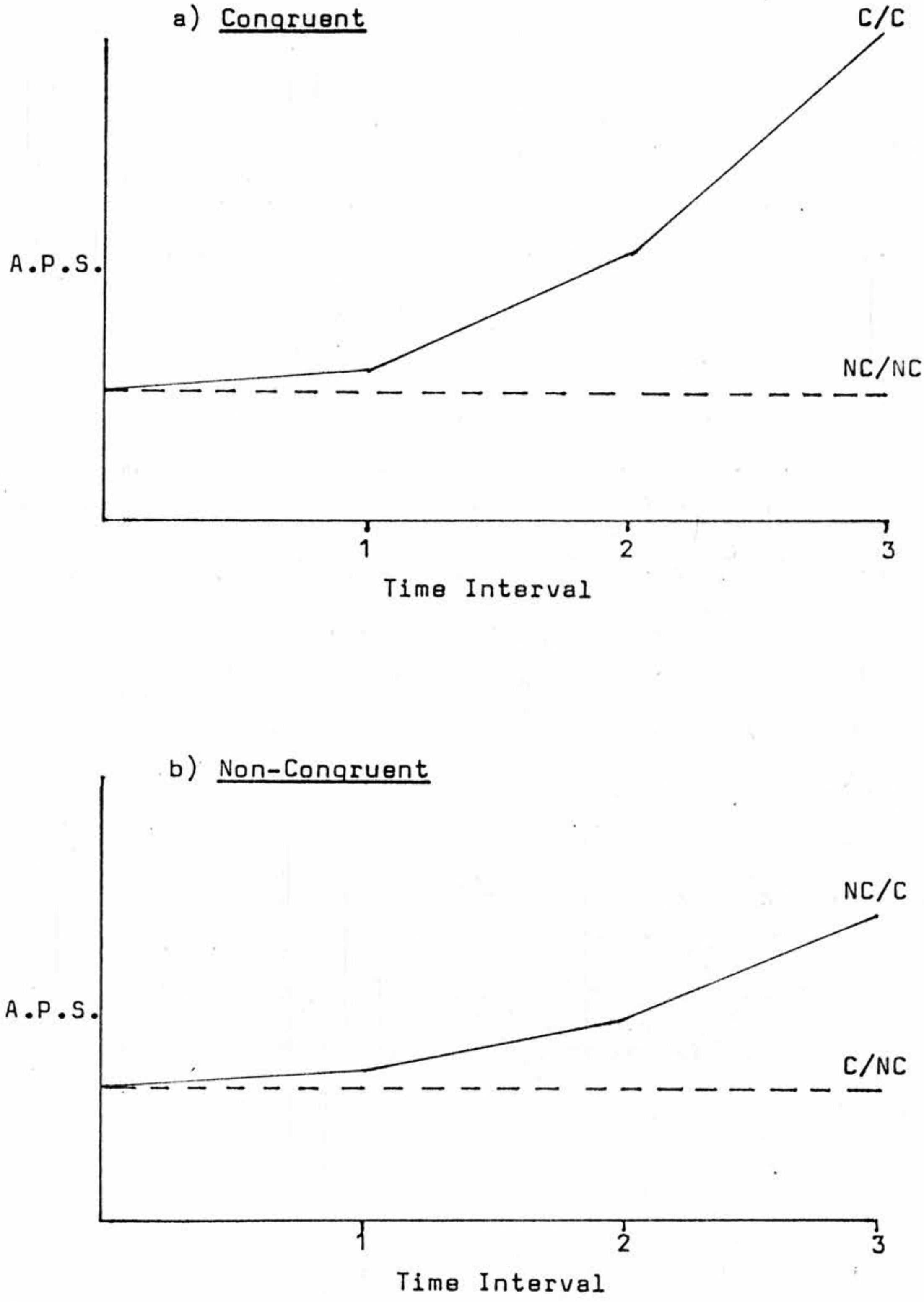


Fig. 6.5: Difference scores for (a) Congruent; (b) Non-congruent conditions

t-tests were performed on the D scores for the Congruent (contact/contact versus non-contact/non-contact) and for the Non-congruent (non-contact/contact versus contact/non-contact) conditions. These were found to be significant at the $p < 0.05$ level and $p < 0.1$ level respectively. However the pattern of the Non-congruent condition is in the direction of pick-up of form, that is the greatest head retraction is shown with the duck receding but with the Sonicguide signalling approach.

This data was broken down further. It was found that there appeared to be an age difference in the responses of infants under 12 weeks as opposed to those over 12 weeks of age. It is seen that in the Congruent condition the younger infants demonstrated head withdrawal much more clearly than the older infants. Fig. 6.6(a) (see over) shows that there is a larger difference in head withdrawal between the approaching object and the receding object for the younger infants than for the older infants. This is in accordance with the predictions made by differentiation theory. However, in the Non-congruent condition (shown in Fig. 6.6(b) (see over) testing form versus rapid learning, we see that the major contributors to form pick-up appear to be the older age-group. In contrast the younger infants show very little difference across the two types of presentation (non-contact/contact versus contact/non-contact).

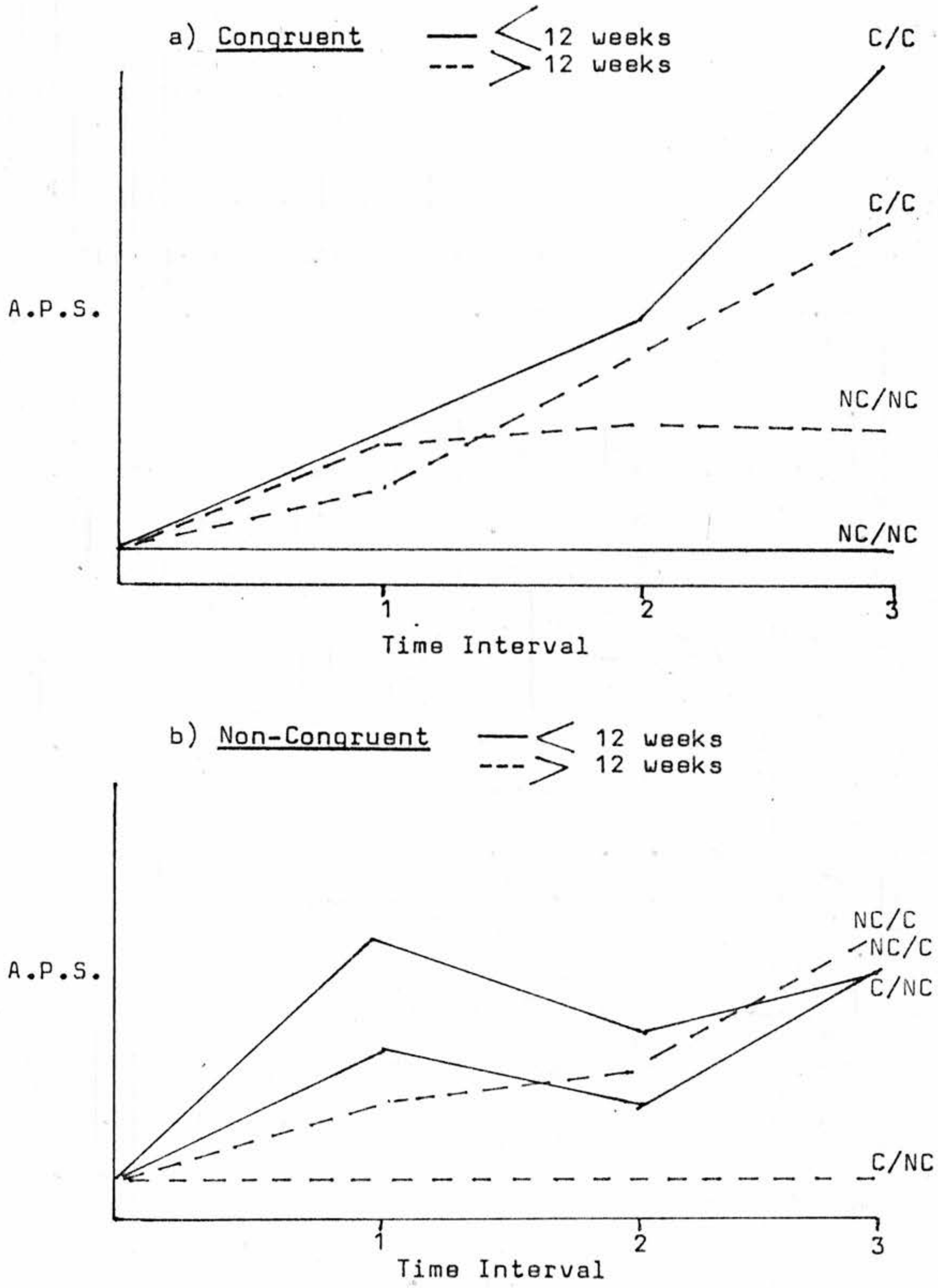


Fig. 6.6: Differences in responses of infants under 12 weeks from those of infants over 12 weeks. For (a) Congruent; (b) Non-Congruent conditions.

This apparent discrepancy is resolved when the change-over from one condition to the other is looked at in more detail. In the case of the older infants, it appears that they continued to respond at the same level to theform change ignoring any change in the contingency of the signal with the event in the environment. With the younger infants, it appeared that they, too, at first picked up the form of the stimulation but that this could be altered by overlaying discrepant information. They continued to show head withdrawal more to the sonicguide specified approach than to actual approach but it appeared that the change in signal was a source of confusion. Because the young infant was exposed to this "discrepant" information only briefly, this "discrepant" information only served as a source of confusion. With the older infants, there was no confusing factor as this information was ignored and treated as discrepant.

DISCUSSION

Firstly, these results confirm the work of Dunkeld and Bower (1980) and Bower, Broughton and Moore (1970 a). Infants did show head withdrawal as a response to an impending collision. The changes in form specifying approach in the Congruent condition are presented in a form which is amodally equivalent to the retinal expansion pattern of a visually specified approaching object. This study therefore avoids the observation made by Bower (1977 d) that looming responses pose problems in interpreting what stimulus it is that the infant is responding to. With a visual stimulus there are several possible alternative stimuli to which the infant may be showing an apparently adaptive response. One possibility is that he may be responding to a specific component of the stimulus and that the response is not therefore really adaptive. (It is, of course, possible that any particular stimulus component is a specifying variable, in the Brunswikian sense; thus blur on the retina could specify the distance of an object or change in blur could specify change in distance.)

In specifying approach of an object by the guide we circumvent this problem of interpretation of the response. The infant cannot, for instance, be responding to the blur of the object caused by the movement changes with a visually specified object. Nor can the results be explained by the infant following the rising contour of the object. Instead, the infant appears either to be picking up amodal form change or else is learning extremely rapidly.

In the Congruent (contact/contact and non-contact/non-contact), conditions, results showed that infants made greatest head withdrawal to an approaching object. These results could be predicted by a differentiation theory. They could also be predicted by a theory which assumes rapid learning in early infancy. The possibility also existed in this condition that the perceptual information the infants were responding to was a change in air pressure. An approaching object will present a form change for audition and vision like that shown in Fig. 1.9 (see page 39). This pattern will also be obtained with the changes in air pressure caused by an approaching object. It could then be that it is a combination or summation (Bower, 1966) of these perceptual stimulus effects (auditory form change and air pressure form change) that the infant is sensitive to. The two would be picked up consonantly.

In presentation of the Non-congruent conditions, however, a decrease in the extent of the looming response occurred. The response in the Non-congruent condition was greater to the non-contact/contact than to the contact/non-contact presentation. This result is not consistent with a rapid learning explanation. If learning had been all-important, we would have expected greatest head retraction to be shown when the Sonicguide was signalling a receding object, at which time the object would have been approaching to contact.

Although, therefore, the looming response was greater to Sonicguide specification of approach, the response was not as great as in the Congruent contact/contact condition. In the Non-congruent condition, during non-contact/contact, the auditory signal would be specifying approach while air movements would be specifying withdrawal. This result would suggest that the change-over was not straightforward and based purely on the form of the stimulation. If it had been, we would have expected to obtain an eqivalent head retraction for Sonicguide specification of approach, whether the guide is specifying approach in the Congruent condition or in the Non-congruent condition.

As is seen from Fig. 6.6(a) and (b), infants older than 12 weeks showed this response to the same extent in both contact/contact and non-contact/contact presentations. They therefore appeared to be going purely by form of stimulation in the manner described above. With those infants younger than 12 weeks, the response in the Congruent condition was still in the direction of sensitivity to form of stimulation. The response was, however, greatly reduced from that shown in the Congruent contact/contact condition. It would appear then that "young" infants respond to form and, at the same time, learn rapidly. Older infants are more directed by the auditory form of the signal. The implications of this apparent rapid learning for a theory of differentiation are considered in the next chapter. Before this, however, we must consider an explanation for the difference in responses of infants under 12 weeks from those of infants over 12 weeks.

This result was certainly unexpected, and could not have been predicted from the results of previous chapters: there should have been no sub-division within age-groups. As an explanation, any account based on pure learning can be discounted. As was stated above, such an explanation is not consistent with more head retraction being obtained in the non-contact/contact than in the contact/non-contact presentations. Nor, on such an account, should there be any age differences in response.

Paradoxically, however, it appears that some form of learning may be able to account for this change in response. Earlier in this discussion, it was reported that approach may be specified by two stimulus parameters. One parameter is the form change through audition characteristic of the guide signalling approach. The second parameter is a similar form change specified by air movements on object approach. As was also stated above, Bower, Broughton and Moore (1970 a) demonstrated defensive responses to an approaching object in neonates. To control for the possibility that it was air movements they were responding to, a shadow-caster was used to present a purely visual approaching object, defensive responses, although less strong, were still obtained. This seemed then to suggest that air movements had little to do with the response.

However, in the present experiment, the possibility exists that these young infants may have been responding to one source of information (visual) and/or alternately to the other (air pressure). This raises the question of how infants combine or cope with more than one source of information. Bower (1966) has suggested that young infants, when presented with more than one source of information, alternate their attention between the components. Babies older than 12 weeks showed an increase in attentional capacity. When presented with various components of a pattern and the whole pattern, they, unlike the younger infants, showed that they recognised that a single component of the pattern was different from the whole pattern. Cohen (1973) too, has also suggested a similar dual process, with transition occurring at about 12 weeks. It would appear from this work then that there are changes in the ways in which infants may combine stimuli. These changes may well account for the age difference obtained here.

If the young infants were alternating between stimulus components - of air pressure and auditory form change - we would expect there to be little difference between the two presentations of the Non-congruent condition. This would be because there is conflict occurring between the specification of approach by the two stimulus components - in either modality. This was indeed the case. If, however, a change in attentional capacity were occurring at around 12 weeks we would expect the infant to then attend to the ecologically more valid higher-order information. The only question to then be answered is which is the more ecologically valid time-change function for amodal presentation of approach - through audition or through air pressure?

If we make the plausible assumption that infants, after having been given exposure to the open air, would extinguish air pressure as a source of useful information about approach, then the answer is apparent. This would suggest that the more ecologically-valid time change function is through the auditory modality. We would therefore expect the older infants (older than about 12 weeks) to respond only to the form of stimulation presented through audition. The similarity of results for these older infants between Congruent and Non-congruent conditions, where the sonicguide specifies approach through audition, would support this. This result, at first seemingly paradoxical, can therefore be encompassed only within a framework which would hypothesise that the young infant is set to respond to higher-order information presented through any modality (through sight, sound or, in the case of air pressure, the very young infant through touch).

CHAPTER 7 - DISCUSSION OF THE THEORETICAL IMPLICATIONS OF THE FINDINGS OF THESE STUDIES

INTRODUCTION

In investigating the possibility, nature and limitations of intersensory substitution, this thesis had four main aims. All involved the use of apartícular artificial sensory surrogate - the Sonicguide. All of these aims were formed on the basis of both theoretical and practical grounds. The first aim was to attempt to answer the question of whether humans of any age can use the device. If the guide could be used, the second aim was to determine whether there were any age differences in its use. Assuming that these two questions could be answered, the next aim was to determine how the guide was being used by subjects. Finally, if age differences were found to exist, the last aim was to determine why there were age differences, that is, what is the nature of these age differences?

1. USE OF THE SONICGUIDE

The evaluation study carried out by Kay (1974) had suggested that very few blind persons could use such sophisticated technological aids as the Sonicguide. A figure as low as 5 per cent had been quoted for the number of blind people who were able to use the guide effectively (Bower, 1977 a). In addition, Kay and Strelow (1977) have reported that only the most intelligent of blind children were able to understand and use the device. The possibility that the success obtained with the blind infant studied by Bower, Watson and Umansky (1979) was due to intervention *per se* also existed. On this hypothesis the guide itself would have contributed nothing to this infant's development, the reason for the amelioration of development being due to the involvement of psychologists and paediatricians. If true, then the results obtained could have been unique and unrelated to the intervention programme with the guide.

The present study has, however, shown that this is not the case. It has also suggested that the view of Kay and his colleagues is over-pessimistic. In the present studies, guide use was demonstrated by some subjects at all ages. This was true for both blind subjects and subjects in whom blindness was simulated. For instance, of the blind school-age sample, Subjects BS, BL, BK and BA all demonstrated responses which showed guide use. Most of the blind infant subjects showed age-appropriate behaviour in guide conditions within a short time. Of the sighted subjects tested under conditions of simulated blindness, use of the device was again obtained to a greater or lesser degree across all ages of subjects.

Theoretical explanations to account for the observation that humans of all ages can to some extent use the guide are numerous. One theory which can immediately be discounted is the notion that there is no possibility of providing information via one sense which is normally provided via another. We do not have to posit a hypothetical extra sensory route for the mediation of Sonicguide information. We can therefore refute Johannes Müller's doctrine of specific nerve energies. However, going purely by the observation that use can be obtained to some degree at all ages, it is difficult to distinguish among other possible theoretical interpretations. A nativist, for instance, would predict no difference in use across ages, an empiricist would predict an increase in use, a differentiation account would predict a decrease in use with increasing age. Before attempting to determine which theoretical interpretation is correct, it is necessary that we firstly look at whether there are age differences in guide use.

2. AGE DIFFERENCES IN SONICGUIDE USE

Although all ages of subjects could use the guide to some extent, the results of Chapters 2 to 5 show that there were age differences in the effectiveness and nature of that use. This could only be determined once strict criteria for assessment of guide use were established. The criteria, which have already been argued for, were the emergence of new behaviours and the immediate transfer of response success to novel presentations. Sonicguide use could be seen to be based on one of two possibilities however. The first possibility, which did not fulfil the above strict criteria of use, was in its use as an operant signalling device.

Numerous instances exist throughout the studies which testify to this type of use, in both blind subjects and sighted subjects simulating blindness. For instance, with blind subjects, the response matching observed with BL, where a particular signal was matched with one particular position, showed operant use. No parallax head movements were observed, nor did he detect any radial position change. Sighted adults, school-children and pre-school children (those who could use the guide) demonstrated the same type of use.

The second type of use in which subjects fulfilled the strict criteria of use - response emergence and success transfer - was evidenced by the younger subjects in the blind and sighted samples. This type of use was qualitatively and quantitatively more effective than the operant use observed in older subjects. In the blind cross-sectional sample, AN, SC, SN, SI and XL all showed transfer to novel presentations. AN and SI, the youngest of the longitudinal blind sample investigated, both evidenced emergence of new behaviours. The fulfilment of these criteria appear to demonstrate perceptual use of the guide. The information provided by a sonic field enables the blind infant to develop along more "normal" lines; if the guide is provided during this perceptual phase of guide use.

A similar result was obtained with the young sighted infants who used the guide more effectively than the older sighted subjects. The cross-sectional sighted infants discussed in Chapter 4 demonstrated reaching responses which were equivalent under visible stimulus conditions and sonic-guide conditions specifying the same stimulus. Reaching was observed to be directionally appropriate, with compensations being made between reaches for changes in radial position and distance. Evidence was obtained which points to the amodal detection of higher-order properties of shape and size as well as the above properties of distance and direction. Immediate response transfer to new object positions was obtained, as well as the mis-reaching appropriate to perceptual (as opposed to operant) use of the guide obtained with a change in guide range.

With those sighted and blind infants who were observed longitudinally, it can be seen that the strict demand characteristics of the tasks presented to them could not be coped with unless the infant had been provided with the guide from an early age. It was not, therefore, that the infant was simply learning to use the guide, in which case the age of commencement of use would have been irrelevant so long as frequency and duration of use was equivalent. The emergence of new behaviours such as placing and independent locomotion testify to the effective usage of the guide as a perceptual surrogate by these subjects.

The presence of an age difference in effectiveness of guide use goes some way to unravelling a possible theoretical explanation to account for perceptual development. Consider, first of all a nativist account. Such an account would state that there should be no difference in guide use across the ages of subjects. The presence of the qualitative differences described is clearly evidence which refutes such an interpretation. A straightforward empiricist account can also be discounted as guide use did not improve with frequency and duration of use. Instead, it seems as if the frequency and duration of use had to be fitted in at the right time in the infant's development to have any real effect on development.

Because young infants showed a higher degree of inter-sensory substitution than older guide users, no explanation for perceptual development based on a compromise of these two extreme positions can be upheld. Consider also the studies which have reported on the differences in abilities of the congenitally versus late-blinded individual. In a survey of the achievements of persons blinded from birth, Kirtley (1975) describes the occupations of many eminent blind people. Not one is a mathematician, supporting the notion that such individuals have difficulty in conceptualising problems of Euclidean space. Ever since the classic Molyneux question (Bornstein, 1979), studies have shown that the congenitally blind are at a disadvantage in comparison to the late blinded in problems which require spatial abilities (Drever, 1955; Hartlage, 1968; Hatwell, 1966; Jastzenbska, 1976; Reiser, Lockman and Pick, 1978; Spigelman, 1976; Warren and Pick, 1970). O'Connor and Hermelin (1972, 1978) have suggested that the world of the congenitally blind is ordered, not along a spatial dimension, but along a temporal dimension. Spigelman's (1976) work also supports this proposal. Von Senden's (1960) description of congenital cataract patients who have their sight restored at a later age indicates that if spatial information is not supplied early in life, then, despite later operations being surgically successful, they may not be psychologically successful in terms of later functional use of that restored vision. (See Appendix III.) This work shows that, unless environmental support is provided at the right time, then re-direction of development along a different course will occur. For the successful development of spatial concepts, there appears to be a critical period during infancy for the laying down of spatial information necessary for the later calibration of space.

For an explanation of why there are age differences in effectiveness of use of the Sonicguide, we must look beyond a compromise of these classic accounts of development.

3. PARAMETERS OF USE OF THE SONICGUIDE

As pointed out in the previous section, there were age differences in guide use. It appeared that the older subjects were using the device in a manner consistent with traditional learning theory. The younger subjects, in contrast, appeared to show qualitatively and quantitatively more effective use. The parameters of the more rapid guide use were the issues investigated in Chapter 6.

One possible explanation for the difference in ability to use the guide is that the information to which the young infant is sensitive is different from that to which the older subject is sensitive. Differentiation theory would argue that the young organism is sensitive to higher-order variables, variables like change in stimulation with time-to-contact or symmetry versus asymmetry in stimulation. In this view, it is the information flow, rather than the specific energy of the stimulus, which is the medium for perception. Some other evidence does exist for the detection by young infants of amodal rather than modally specific properties of information. For instance, Day and Mackenzie (1973) have shown that infants detect the higher-order variable of shape rather than the competing lower-order variable of orientation. Evolution would not, in this view, have acted to produce structures sensitive to specific sensory information. Instead, evolution would have acted on the genes to produce perceptual structures which are sensitive to information without reference to modality of sensory input. The alternative to this view, which would also account for the younger infant showing better use of the guide, is based on the notion that the young organism learns more rapidly than the older member of the same species.

The results of the study presented in Chapter 6, in which these two possibilities of rapid learning versus detection of higher-order variables were put into conflict, provided some evidence for the latter parameter of use. It appears that the young infant is indeed sensitive to higher-order variables, such as distance change, size, direction and texture. Nevertheless, the results obtained were not entirely clear-cut. Instead, they indicated that the young infant appeared to be responding to the amodal properties of stimulation <u>and</u> showing rapid learning. This seeming paradox will be returned to later.

4. EXPLANATION OF AGE DIFFERENCES

This is, understandably perhaps, the most important and the most difficult question to answer. The provision of an answer necessarily involves looking at the process of development and the possible mechanisms underlying this process. There are several explanations available for the age differences observed in guide use. Some of these explanations are more tenable than others.

(a) <u>Traditional Learning Theory</u>: This account is the most obviously incompatible with the results obtained. According to this view, any increased exposure to the Sonicguide should result in increased effectiveness of use. Frequency and duration of exposure should be all-important; any differences in frequency and duration should result in differences in use. The traditional operant parameters should be effective at all ages. The results of Chapters 2, 3 4, 5 and 6 point to this argument being implausible.

The more sophisticated version of this theory put forward by Gibson and Spelke (1981) also cannot account for the results obtained in this thesis. Recall that they too assumed an associationist stance. They believe, however, that the associations involved are between higher-order invariants. The higher-order invariants they posit are sensorily-specific. For instance, according to Spelke (e.g. Spelke, 1979), the infant detects one higher-order invariant in the event sequence presented to him which is visually specified. He also detects an invariant in the event sequence which is auditorily specified. He then associates the two through traditional learning parameters. This results in intermodal perception, the infant learning to detect that certain modality-specific events can be part of the same event. Again, such an interpretation cannot account for the qualitative and quantitative differences in effectiveness of use of the guide detailed in Chapters 2 and 4 (the cross-sectional studies). The direction of effectiveness of use is a decrease with increasing age, not, as they would predict, an increase with increasing age. These two accounts can therefore both be dismissed.

Three possible explanations remain which can account for the age differences in performance. The first is based on the work of Piaget (1936). The second explanation is that based on Werner's model of differentiation (Werner, 1948). The third is in the differentiation account offered by Bower (1979 c, d).

(b) Piagetian account: Piaget has put forward the view that emerging behaviours require environmental support. Without that environmental input, the emergent behaviours will simply drop out. Perceptual information is seen as alimentary to the organism, rather than prescriptive for development. It is motor behaviour or action which is primary. Behavioural development necessitates functional "aliment" (Piaget, 1936, page 449) or nourishment. This "aliment" in perceptual information could be provided in the form of either light or through a sonic field. For example, in the emergent phase of prehension, the perceptual information seized could come either through light or through the guide. However, it must be presented during the emergent phase of the behaviour.

The second Piagetian notion that must be introduced is in his idea of a "schema". Particularly in infancy, this term is prominent in Piaget's account of development. Like most Piagetian terminology, it is defined more by example and usage rather than by more specific definition. A schema is a cognitive structure referring to a class of similar actions. These actions are closely intermeshed in behavioural sequences. Thus there is the schema of sucking, the schema of sight and the schema of prehension. The term implies not only the class of behaviours to which it refers but also implies a cognitive structure which predisposes the organism to act on objects. It is a psychological structure which functionally incorporates "aliments" or is nourished by them. Again an example may help to illustrate this meaning. Consider the schema of prehension. For Piaget this consists of several interwoven elements - the arm extension, finger-curling and arm retraction. Together they constitute a repeatable whole. The schema, as an entity, is manifested when objects are situated near the infant. All objects within reach therefore become "aliments" or serve to nourish the schema of prehension.

A schema is similar to a concept in that it refers to a class of actions - no particular reach is exactly repeatable but each reaching sequence has certain characteristics in common with other reaches. Piaget distinguishes between a schema and a concept, with the schema being a type of sensori-motor concept. Like a concept, it involves classes and systems of classes, but is the motor equivalent of these.

The account given above would go some way to explaining the results obtained in this thesis and elsewhere. This account would explain why the congenitally blind are at a disadvantage in comparison to the late-blinded in spatial tasks. Recall that the work of O'Connor and Hermelin (1972, 1978) and Spigelman (1976) seemed to suggest that the congenitally blind operated on a temporal rather than a spatial framework. For them, the "nourishment" presented during the sensori-motor period is dependent upon the input of perceptual information which comes in a temporal form. The psychophysics of passive sound emanating from a distal object provides little perceptual information as to spatial relations (Bower, 1977 a). There is therefore no possibility for schemas to emerge which can provide for the development of spatial concepts. Schematisation takes place, instead, on a temporal dimension. The late-blinded do not have this disadvantage having been provided with visual information to calibrate space during schematisation in the sensori-motor period.

In the results obtained with the guide, a Piagetian account can explain why the young blind infant should be able to use the guide rapidly. Developing behaviours require perceptual aliment - whether through vision or the guide. If the signals from the guide are presented during this phase of schematisation, then these signals may be used as perceptual information to nourish the behaviour.

This theory should, however, propose that sighted subjects of all ages should have been equally able to use the guide. With perceptual information having a purely alimentary function, it should make no difference as to the manner in which the spatial information is provided. For the young infant, the modality of input of the spatial information should be irrelevant, either modality should be seized on by the emerging behaviour. For the older subject, with whom schematisation has already occurred, spatial information is already calibrated through vision. Presentation of this information through audition should be equally useful however. The observation of a laborious process of learning through response matching, i.e. operant guide use, does not concur with the notion of a schema. For instance, if a schema for prehension has developed in which spatial information has been calibrated already, then the subject should be able to manifest this schema regardless of the modality of aliment.

The results obtained with the adult blind subjects studied by Kay (1974) also do not accord with the Piagetian view. These subjects were already mobile and yet, when presented with Sonicguide information as to distal objects, had great difficulty in incorporating it into the schema of "locomotion". A laborious, often unsuccessful process, was necessary to establish even limited guide use.

One possible way out of these difficulties for a Piagetian interpretation would be to invoke Piaget's distinction between a "schema" and a "scheme". It will be recalled that a schema is an action sequence germane to a class of stimuli. The stimuli necessary for nourishing a particular schema may be sight, sound, touch or other. The notion of "scheme", however, posits that a particular action sequence is dependent on a specific stimulus input. If the action sequence is designated as "R", and the input as "S" then the S - R connections are specific. On this hypothesis, action sequences or emerging behaviours would require, for aliment, one particular set of stimuli, for example those provided in soundwaves through audition. On this hypothesis, the blind adults studied by Kay would have developed a set of behaviours which could be termed "mobility". This mobility scheme would be dependent on a certain type of stimulus - through natural sound interference patterns, for instance. The signals of the guide did not conform to this type of stimulus, even though it provided spatial information. Any use of the guide would therefore have to involve laborious construction of new schemes. Similarly, the difficulties posed by the older sighted subjects' use of the guide, described above, could be explained in this way.

However the notion of a scheme specific to one class of stimuli does not concur with all of the results obtained in this thesis. The performance of the longitudinal sighted subjects cannot be understood in these terms. It will be recalled that these subjects demonstrated greatest effectiveness of use at the emergent phase of new behaviours. Once the behaviour had been established, guide use then dropped off. During its emergent phase, the behaviour would be almost as likely to be in evidence under guide conditions as in the light. For these subjects, emergence of new behaviours could seize on, or be nourished by, either light or the information provided by the Sonicguide. In the light they could use vision. In the experimental situation, with the lights switched off, nourishment of the particular emergent behaviour could be given by a sonic field.

This result is at odds with the idea of a scheme. On such a prediction, behaviours which are emerging should be manifested under only one set of stimulus conditions - either in the light <u>or</u> via a sonic field. In contrast, behaviours in their emergent phase seemed to be generalised to more than one type of stimulus. The longitudinal sighted infants were able to seize on either type of stimulus depending on the prevailing conditions.

One set of results is therefore at odds with the notion of a schema, action sequences which can use as aliment a generalised set of stimuli. As shown, a schema interpretation does not fit with the observations of operant usage, nor with the obvious problems that the older sighted subjects had in guide use. To counter this, behaviours specific to one class of stimuli - a scheme - could be invoked. The evidence culled from the longitudinal, sighted users is, however, at odds with this type of view. These two notions - schema and scheme - cannot both be correct. They cannot co-exist. Like the Piagetian idea of class inclusion and exclusion, a schema would have to include all schemes. If, on the other hand, the notion of "scheme" had explanatory value, then all other schemes would have to be excluded.

The results obtained in Chapter 6 show too, that perceptual information does not perform a purely alimentary role in development. In contrast to Piagetian theory, perception appears to perform a prescriptive role in development. This would, at first, appear to contradict the results of Fraiberg (1977) which suggested that one action (auditory-manual co-ordination) was a prerequisite for another action (crawling). This would suggest that it is action which determines later perceptual calibration of space. However, this ignores the fact that it is a third factor - blindness - which cuts across both of these actions. It is vision providing spatial information which allows the later emergence of both these behaviours or actions. It is therefore perception which is performing a prescriptive, rather than alimentary, function in development. Chapter 6 provides evidence for the amodal pick-up of the higher-order invariants for calibration of a perceptual space necessary for later action in that space. Perception does not have a behavioural basis.

Piagetian theory would seem, therefore, to be unable to account for all of the results obtained in this thesis. Next we shall assess the Wernerian account, which provides an alternative explanation for these results.

(c) Wernerian account: Werner suggested that development was a process of differentiation. His theorising was generally phenomenological and incorporated comparative psychology, perception and the "mental functions *per se*" (Werner, 1948). Development, in this view, progressed starting from the synaesthesia of the neonate, going from syncretic to discrete perception. His was a nativistic stance, regarding differentiation as a genetically determined process, with development proceeding from the global or undifferentiated to the differentiated and then to hierarchical integration. The three states involved in differentiation are regarded as qualitatively different. In this account hierarchical integration, selective recombination or reintegration of previous sensory inputs, would be the last stage to occur.

In the undifferentiated organism, perception is synaesthesic. Stimuli are not only experienced in the modality of transmission but also in all other sensory modalities, due to the immaturity of the neural connections in the infant brain. Up to the stage of differentiation, the possibility of sensory substitutability will therefore exist. A novel sensory system will slot into the infant's perceptual system because of the supramodal mediating linkages mediating sensory information. After differentiation, modality-free pick-up of information is lost; differentiation occurs with loss. The "global" response of the synaesthesic infant is replaced by modally specific responses after a period of reintegration. The Wernerian account of differentiation has received some recent support in the work of Strauss and Stavy (1979). They have reported other examples of U-shaped curves in development, where a particular behaviour waxes and wanes and then possibly waxes again. The waxing, waning, waxing are seen as the global, partially differentiated and then co-ordinated or reintegrated systems, respectively.

Such an account would certainly seem to be consistent with many of the results obtained in this thesis and elsewhere. It would explain, for example, the difficulties experienced by the congenitally blind in spatial tasks (e.g. Drever, 1955; Hatwell, 1966; Kirtley, 1975). Not having experienced the rich sensory input afforded by vision prior to differentiation, there is no possibility for recombination along this dimension. Spatial concepts therefore remain inaccessible to this group. Secondly, this account would anticipate the qualitative difference manifested by the cross-sectional sample of both blind and sighted subjects. If the novel sensory system of the guide is presented to subjects before differentiation occurs then they should be able to use the guide effectively. If it is presented after differentiation has occurred, then the consequent loss of modality-free pick-up of information should result in qualitatively poorer performance. Both of these predictions were borne out. Thirdly, this view would account for the results obtained by Kay with adult guide users. Mobility without the guide had already occurred, with recombination of modality-specific sensory input discounting the possibility of pick-up of Sonicguide information.

Although this theory would seem to account for many of the results presented here, as with Piaget's account, it cannot explain all of the results. In the first place, on the most extreme interpretation, no guide use at all should be observable after differentiation has occurred. This is because sensory reintegration would have nothing to reintegrate - the guide information had not been provided during the period of synaethesis. The organism could not therefore make use of the guide's echoic information as it does not rely on interference patterns. The only way out of this would be, if, during the period of synaesthesia, the infant were registering higher-order variables. This would be in addition to the registration of lower-order variables and their supra-modal equivalents. This would entail the undifferentiated organism having to process more information than the differentiated organism. This is contrary to the results of all other studies which suggests a growth in processing capacity during development (see, e.g. Bower, 1979 a).

If we adopt a slightly less extreme Wernerian account and only say that there could be some minimal use (post-differentiation) but that there would be a qualitative difference, then this too encounters problems. Strauss and Stavy (1979) would say that, because differentiation is a biologically determined process, then there must be a universal drop in guide use after differentiation has occurred. There would therefore have to be a qualitative difference in use for all subjects. No such qualitative difference was evident with the longitudinal sighted subjects, nor with the longitudinal blind subjects. According to Wernerian theory, development should become more and more retarded in those subjects who were provided with the guide at an early age. This is because the guide does not provide a rich synaesthesia input, instead only providing amodal information. On this view, therefore, the infant should become more and more retarded in its development. Particularly with the sighted longitudinals, who have this synaesthesic input provided via the visual modality, progressive retardation should be obtained. The guide, for them, should be totally irrelevant in its information content as they would then be relying on visual input. The increased use at certain points in development is incompatible with this account.

A final point that should be noted is that there would appear to be no obvious means of testing experimentally for synaesthesia in neonates. There is no clear way of testing the hypothesis of this type of phenomenological theorising.

(d) <u>Bower's account</u>: Bower's general theory of development, as expounded in his most recent publications (Bower, 1979 b, c, d), has the following characteristics. Development is seen as a process of differentiation, whereby powerful, abstract ideas are made more specific, that is more differentiated. The differentiated form is not, as in Werner's account, regarded as qualitatively different from the former more abstract form. It is therefore differentiation which occurs without loss. However, gains in precision, or specificity, may result in temporary losses in power or generality, leading occasionally to dips in development, the so-called U-curves in development. Developmental change is not seen as the result of maturation or learning or some simple combination of these.

The most important explanatory factor in development for Bower is the cost/gain ratio. The idea here is that every developmental step involves cost to the organism. For example, it may demand that more information be processed. The gain may be enhanced success or decreased environmental complexity or something of the sort. The paradigm case for Bower is the step in the development of the object concept from reliance on place and movement as identifying criteria to reliance on features. This involves a cost - the processing of the shape, size and colour of objects - and a gain - a vast reduction in the number of "objects" the infant has to deal with.

So far as I know, Bower has not applied this kind of analysis to perceptual problems of the kind discussed in this thesis. The following outline analysis is therefore a speculative extrapolation from theory rather than an account of an existing theory. Bower would certainly predict that young infants respond to higher-order variables in stimulation. Indeed he has claimed that they can only respond to higher-order variables, with modality specific variables - e.g. colour - relatively or totally inaccessible. Why then should there be a decline in modality-free responding? A second feature of Bower's theorising must be introduced here, the idea that stimulus inputs are mapped on to an internal representational system, a kind of universal language, that then controls behaviour. He posits that these internal representational systems compete for space, with the least useful being deleted, a notion akin to Bateson's (1973) "ecology of mind". Thus the congenitally blind lose the system for describing three-dimensional information, while the congenitally deaf lose the system to describe temporally ordered information. If this loss has occurred, then subsequently presented information - in the case of the blind, 3-dimensional information - will be literally meaningless, since it cannot be referred to a representational system. Older blind subjects should thus find it difficult if not impossible to use the sonicguide. This view is superficially similar to Piaget's, outlined above, but has different implications for therapy. These will be discussed below.

If Bower can account for the pattern of change seen in the blind, can he also account for that seen in the sighted subjects studied in this thesis? Can he explain what looks like differentiation with loss? His explanation for developmental changes in speech perception outlines a possible mechanism. In discussing why infants lose the ability to discriminate speech sounds, he draws on information theory, arguing that readiness for a large range of sounds that *might* occur will cut the processing space available for the sounds that *do* occur. The cost-gain ratio thus favours a restriction of the set. If we envision the young infant as set to detect spatial information through all modalities, the information space available for analysis of input through a given modality will thereby be reduced. It would thus be functional to differentiate, specialising one modality for the concerns of the moment. Since the sighted infant has all of the rich possibilities of light available to him, it is no surprise that vision rapidly becomes the predominant modality for the pick-up of spatial information, and no surprise that this restriction occurs rapidly. However, since the spatial representational system remains intact in sighted subjects, they should retain the possibility of using non-visual information for spatial purposes. That they do is attested by the greater success of late blinded subjects in spatial tasks. However, in terms of costs and gains, Bower would have to predict that late-blinded subjects would do better than sighted blindfolded subjects. This prediction is borne out by the work of Hatwell (1966), Kohler (1956) and Spigelman (1976) who all found that late-blinded were better than sighted blindfolded subjects who, in turn, were better than congenitally blind subjects on spatial tasks. The continuing performance of the longitudinal sighted subjects studied in this thesis can be understood in these terms. In light they used vision. The laboratory surroundings, the plunge into darkness, switched spatial readiness from the visual to the auditory modality.

In terms of practical applications, Bower would have to predict that the late-blinded should be able to use the sonicguide, regardless of age. The congenitally blind are a different matter. Bower has argued that any intervention must reflect the representational system the subject brings to a task. If the congenitally blind cannot represent spatial information, there is no point in presenting them with spatial information. Successful intervention will thus depend on our ability to translate spatial information into terms that the blind subject can represent. Any such programme clearly depends on a better insight into the representational system of the congenitally blind than we have at present.

Although Bower's account would appear to be more consistent with the results of this thesis, there are a number of inherent problems. The first difficulty in the account of differentiation offered by Bower is in the descriptive nature of the theory as it applies to the type of problem discussed here. Although not at the level of "black box" psychology, his account would seem to offer little in the way of prediction. Results are accounted for post hoc with no description of processes of transition. His theory does, for instance, offer a means of defining the terms "abstract" and "specific" in behavioural terms by recoursing to Bateson's use of the Theory of Types. It does not say how abstract ideas become more specific other than through the ratio of costs and gains, an account which has only been expanded in his work involving the object concept paradigm.

Bower's account is one of differentiation occurring without major loss. Loss, when it occurs, is only temporary leading to occasional dips in development. If this account of differentiation occurring without loss were taken to its extreme then this view would clearly not fit with the observation that, although all ages of subjects could use the guide to varying degrees, there were age differences in use, for instance in the sighted subjects. The opposite extreme, differentiation with loss, has been shown to be untenable previously (in the Wernerian account). Bower therefore proposes that although amodal perception later incorporates modality-specific perception, competition between and within modalities occurs and is resolved on the principles of an ecology of mind. Therefore, for instance, vision is used for calibration of space while audition is taken over by speech perception. This view would predict, therefore, that the more "free space" available in that modality then the easier should sensory substitutability be. This is contradicted by the work of von Békésy in substituting tactile for auditory information. Despite the tactile modality having this "free space", adults did not show immediate use of this information. The same process of learning seemed to be involved as for adult pick up of information from the Sonicguide substituting for vision.

A further difficulty with Bower's account concerns the explanation for the apparent use of the guide by the older subjects as an operant signalling device. This type of use, emerging only after laborious learning, was evident with some of the adults studied by Kay, as well as by the older blind subjects in this sample. If operant use is demonstrated, this would seem to require the assumption that some form of representational system for spatial information is at work. There are then two problems. Firstly, sighted subjects, already possessing such a system, should show transfer to sonic information more rapidly than blind subjects. However, older sighted subjects seemed to take longer to demonstrate operant use, if they showed use at all. Secondly, congenitally blind subjects, who apparently do not have such a representational system, should not be able to use the guide, either operantly or otherwise. In contrast, we see that some of the congenitally blind subjects were able to use the guide in this operant fashion.

Bower could handle these last two points if he were to posit that the older congenitally blind do have some system to represent space, but that it is relatively inaccessible. The guide information would latch onto this system and in some way "tune it up". This process could then depend solely on a cost/gain analysis. If this interpretation were correct, then an increase in gains over costs should give an improved performance. Increasing costs over gains should, at best, show no change. What is the evidence on this? Most of Kay's adult subjects could not use the guide, even after prolonged use -wwhich should increase the gains over costs. The longitudinal sighted subjects also did not show a uniformly increasing performance. Moreover, if it were simply a case of mapping a novel sensory input onto an already formed spatial representational system, plus a change in the gain/cost ratio, then there should be no difference between the sighted semi-longitudinal and longitudinal subjects. In the case of the semi-longitudinals, the spatial system was already there (sight), and the ratio of gains over costs was changed with extended wearing of the guide. There was, however, no improvement. In the case of the longitudinals, a spatial system was also already present, and yet the increase in gains over costs did not result in a uniform increase in performance.

The idea of a cost/gain ratio presents a number of additional problems. As was stated above, development incurs costs while at the same time providing certain gains. An increase in the costs incurred should retard the process of transition, an increase in gains should accelerate the particular change. One problem with this is how the cost/gain ratio is perceived by the infant. Does the infant have to perceive a change in the ratio? If so, this requires that he has some idea of his own action upon the environment, and thereby some awareness of self and of his own personal efficacy. This awareness of personal efficacy is likely to increase with age; this increase should result then in decrement in performance with the guide for the longitudinal subjects, since in comparison to vision, the guide is less useful in most situations. These subjects did not show a uniform drop in performance. It is equally possible, that the increase in awareness of personal efficacy could result in increased performance in the specific situation of the laboratory. If so, then it would be expected that performance in guide use would have increased consistently over sessions. Instead, it showed alternate increase and decrease in use. The cost/gain ratio would suggest that if the guide is increasingly perceived as a poor substitute, then use should drop out altogether. This was obtained with the cross-sectional sighted but not with the longitudinal sighted subjects.

A further problem concerns the effect of the cost/gain ratio during the process of transition from one developmental step to the next. During such a step, a temporary loss in power would be expected - a dip in development. This would be consistent with a change in the cost/gain ratio. If so, we would expect that, at the point of transition, least performance with the Sonicguide should occur. We should expect, in other words, that during the emergent phase of a particular behaviour, minimal guide use should occur. This again was not the case. In the blind subject, SN, the emergent phase of behaviours produced maximum guide use. With the longitudinal sighted subjects, the maximum evidence of effectiveness of use occurred during the emergent phase of any behaviour. Despite the gains outweighing the costs after this phase, guide use fell back to a minimum thereafter.

A further problem which these results pose for Bower's account concerns his idea of the infant's representational system in relation to the cost/gain ratio. Because of the functional requirements of specification through an ecology of mind, representational systems compete, with sight mapping a 3-dimensional space. If the extreme view is taken that there is then no possibility of space calibration under any other modality, there should then be no use of the guide - operant or otherwise. The results presented show that this cannot be true. If instead we say that spatial calibration, having been specified in one modality, is still present amodally, what should we find? For the sighted subjects, this would suggest that we need only change the cost/gain ratio to obtain a change in guide use and show improvement in performance. Again this does not fit with the results obtained. For this to be true, no change should be found between the semi-longitudinal and longitudinal groups. If we only have to change the cost/gain ratio to change performance, then the increased exposure which was given to both groups should result in equivalent increases in performance in both. It did not. Instead, the longitudinal sighted group showed qualitatively and quantitatively better use at certain points in their development.

A final problem concerns the longitudinal sighted group. As shown in Chapter 5, the subjects in this group did not show a uniform effectiveness of use. AH, on twice-weekly visits, was consistently better. However, RG, of those on weekly visits, was far superior to the other subjects. The problem then is defining the reasons for the difference in use. Increased exposure may be of some relevance, but it cannot account for all the variance. Whatever the factors were which could have caused these differences, they may have been due to learning or to development. The question is which.

Clearly then, Bower's account encounters some problems in dealing with all of the results. It would seem that his account does fit with more of the evidence than any of the others. It would seem, though, that a more complete explanation requires some change in his account of differentiation theory. This will be considered in the last part of this thesis.

A POSSIBLE RE-INTERPRETATION OF DIFFERENTIATION THEORY

The position adopted here is one that still advocates differentiation in development under environmental control. Development is not incremental with some simple combination of genetic plus environmental influence at work. It is not that initial amodal experiences are replaced later by modally-specific experiences. Instead, it is seen as a process of specification occurring without the loss of the earlier amodal pick-up of information. The later, more specific experiences overlay the earlier abstract or modality-free ones. A theory of differentiation in development is in accordance with recent evidence coming from embryology and microbiology.

In the 1950s, Sperry's (1956) work on amphibians had suggested that function had no role to play in neural growth with the whole process being genetically determined. More recently, however, his work has been called into question by a series of experiments. Gaze (1970) has shown, in hemiretinal transplants with the frog, that environmental influences can affect processes of gene expression. Changeux and Danchin (1976) reviewed research on cloned organisms which, although genetically identical, show differences in neural organisation - differences which had to have been due to differences in environmental influences.

The evidence presented in this thesis suggests that young infants do indeed respond to higher-order variables of stimulation. These invariants are picked up amodally without reference to any particular sensory modality. This suggests that the structures for information pick-up which the infant has at birth are not sensory-specific structures but perceptual structures which have evolved for detection of these higher-order variables, picking up information about distance, direction, size and so on. The information supplied by the signals of the guide would not appear to be simple information, if we consider simplicity/complexity as a specific sensory attribute - the sound at the ears is not simple. If the information contained in the signals is not, however, detected in this modality-specific fashion, but instead the form or amodal properties of the information are detected, then the information is not complex. The information is not, in other words, complex to an organism who finds meaning in information through its higher-order properties.

The results are consistent with evolution having acted, not to present the organism at birth with structures which are sensitive to specific sensory information, but with perceptual structures set to respond to information which can be presented through any modality. Thus distance and distance change is not absolutely calibrated at birth - it would be non-functional if this were so - but are calibrated with reference to amodal information of intensity and change in intensity of stimulation. Differentiation is an epigenetic process where maturational and environmental influences interact, with the latter directing and re-directing the former.

To investigate what these environmental inputs are and how they contribute to the process of differentiation, it will be useful to consider the sighted cross-sectional and longitudinal subjects. It will be recalled that guide use dropped out altogether and then resumed at some later period. This was also reported with one of the blind longitudinal subjects, <u>SN</u>. At the time it was pointed out that such a result discounted development on any simple compromise of maturational or environmental influences. As with <u>SN</u>, the results obtained with the sighted longitudinals showed resurgence of guide use during the emergent phase of new behaviours. Placing, crawling and walking, where they occurred, were demonstrated concurrently in both modalities. This would suggest that in development there are parallel processes. Such behaviours will emerge at the same time in all modalities as long as the spatial information is provided during the amodal phase of information pick-up.

Such an indication of parallel processes in development is in accordance with an epigenetic theory. At various developmental "nodes", there are several possible alternative pathways which can be followed. The nature of the environmental input at these "nodes" will determine which pathway the infant will proceed along. There are several possible pathways to arrive at the next "node", some of which may mean acceleration of deceleration in rate of arrival. Some may indeed mean that the next "node" is not arrived at. One example would be the congenitally blind child who, without spatial information, travels along a pathway which does not allow for the development of spatial concepts. The nodes may be maturationally determined but without environmental support, the resultant response would die out. This again would lead to re-direction of development, as in the congenitally blind child.

The developmental process is seen as one of differentiation without loss. Development can proceed along one of two pathways - in the light or using a sonic field. Both of these are dependent on the input of information during the initial phase of sensory substitutability. If the information is not provided during this "perceptual" phase, its use becomes dependent on a system which functions in a modality-specific fashion. Thereafter, the information will be used in this way which in turn will provide for a different pathway in development.

This type of account of development is not one which sees development as a process of growth akin to physical growth. Instead it is a process which involves direction and re-direction with paths running in parallel with each other. So far, however, nothing has been said of why one process should be preferred to another parallel process in development. The question then is one which investigates the environmental inputs which cause this direction and re-direction.

From comparison of <u>AH</u> with the other sighted long-term users it seems that a surprisingly simple explanation can be offered. Like the other subjects in the sample, he showed alternate presence and absence of guide use. In comparison to the other subjects in the sample, he was the most effective user of the guide during the emergent phase of new behaviours. For instance he showed great facility in negotiating the obstacle course while crawling, and the results of the placing task were almost as good in sonic conditions as in light. It will be recalled that this subject was given greatest exposure to the guide, with twice-weekly visits. This would seem to suggest that increased effectiveness of use was simply due to increased exposure - a straightforward explanation. This is only half the explanation, though, as it does not account for the later drop-out of the behaviour.

It seems possible that the drop-out is, as in Bower's account, due to costs and gains but between parallel processes of development. The only assumption that would need to be made on such an argument is that development is parsimonious, proceeding along the most economical path, which would clearly be functional to the infants. On this view, at developmental nodes the infant could proceed along a number of parallel paths. Certain of these paths will be more successful for the infant - that is they will involve fewer costs and greater gains. For the sighted longitudinal users, at the emergent phase of new behaviours two possible pathways would be available. The first is to use vision - a possibility which affords greatest gains with least costs. The second is to use the guide - appossibility which does have gains but only in a specific situation. It also had certain costs, with the sound competing against other auditory information, and with it being impossible to use it outside of the experimental setting. It is not surprising, therefore, that the latter should not be used and the former take over.

For this suggestion of selection from parallel processes through an evaluation of costs and gains to be true would, however, seem to obscure any distinction between learning and development. Before discussing this more fully, recall the results of Chapter 6, in which young infants appeared to be responding both to form of stimulation (i.e., higher-order variables) and showing rapid learning. At first this would seem to discount differentiation as an explanation, until we recall that the essence of this theory is that environmental input can serve to direct and re-direct gene expression. The question is <u>how</u>. It would seem necessary to distinguish between the operation of costs and gains at an earlier as opposed to at a later age - otherwise the older sighted subject, given the opportunity should be able to use the guide as effectively as the young infant so long as the gains outweigh the costs.

Bower (1979 a) has suggested that in any given learning situation there are a number of differant levels of learning that are going on. One example he takes is that of an infant in a conditioning task:

"The child is again learning three things.

Level 1 When I kick my foot the mobile goes round.
Level 2 I can control events in the world.
Level 3 The world is a consistent and orderly place."

(Bower, 1979 a)

Adopting a differentiation stance, he argues that in development Level 3 precedes Level 2 which in turn precedes Level 1 learning. Instances of the Level 3 type of input are numerous in the young infant's world, so this would most likely be the first type of learning the infant acquires. For this to occur there must be some perceptual structures which pick up invariants in the infant's world. The argument has already been proposed for the presence of these structures and the type of information they are set to pick up. Without these perceptual structures the world would remain in constant flux for the infant.

Functionally, it would be adaptive for the young infant to pick up this type of higher-level information that the world is a consistent and orderly place. The only assumption we would need to make is that it is environmental input which determines the rate of learning or the rate of development (but see below). Normally, the infant would never be exposed to disconfirmations i.e. that the world is not consistent. In the experimental set-up of Chapter 6, however, it became possible to present the infant with disconfirmations of his world being a consistent world. How should the infant respond when a disconfirmation like this is presented? It appears, at first, that with rapid learning the "young" infant can adjust quickly to the new contingency. Otherwise why should the older infant not have picked up the change and altered his response? An alternative explanation would be, however, that the higher-level learning involved with the younger infant serves to re-direct and determine future learning. On this argument, for the older infant in that experiment, having already learned that his world is consistent, no opportunities to change this can occur, the higher-level learning serving to re-direct all future lower-level learning. The distinction between these two possibilities - rapid learning versus learning of a higher order - is important. On the latter hypothesis, it is not that the learning is more rapid in the younger infant but that the learning is of a different type. The earlier higher-level learning re-directs all later learning in the older subjects.

The problem with this type of view is, as said, that it appears to drop any distinction between learning and development. Earlier, in Chapter 5, it was pointed out that the essence of epigenesis in differentiation theory is that of irreversibility, with environmental input producing structural modifications in the brain that are irreversible. By contrast, learning produces changes which are reversible, through extinction for example. It seems then that any distinction between learning and development must fall down. This distinction need not, however, fall down if we recall the lack of development of spatial concepts in the congenitally blind alluded to earlier in this chapter. The late-blinded child does, however, develop adequate spatial concepts at the same time as the sighted child. It appears that changes which are themselves reversible may produce irreversible effects.

In the experiment reported in Chapter 6, a similar process appears to be occurring. The change in the contingency of the information presented by the guide may be reversible though the pick-up of the information cannot be changed as the perceptual structures picking up this information are present at birth. If the "young" infant (i.e. under 12 weeks of age) is alternating between the two sources of higher-order information presented in the Non-congruent condition (but presented through the one "perceptual" structure), then this conflict could result in equivalent responses to the two perceptual stimuli (form changes through air pressure and audition). That the detection of the Non-congruent was not strightforward, but disturbing to the infant can be seen by the patterns of Fig. 6.6 (b). The smooth increase in head pressure obtained with all infants in the Congruent condition, and seen with the older infants in the Non-congruent condition, was not seen with the younger infants in the Non-congruent condition. Instead, with these infants, in both non-contact/contact and contact/non-contact presentations, there was a large fluctuation in head pressure. For these younger infants, the two sources of higher-order information were conflicting with the rule which was still being established that their world was a consistent world. Both groups of infants were sensitive to amodal information. With the older group, however, through competition for space, one type of information had become more useful than the other.

That this reversible change (reversible here experimentally with this type of device) concerning the infants' world can lead to irreversible effects is testified too by the results with the infants older than 12 weeks. Despite reversing this information, these infants, having attained the Level 3 information of a consistent world, showed no change in response to the change in the information provided by the guide. The initial learning can therefore be reversed but once acquired this leads to irreversible effects.

SUMMARY

This thesis has shown that at all ages tested, some subjects demonstrated intersensory substitution and could make some use of the sonicguide. Across age groups there were consistent differences in the effectiveness of that use. A theory which suggests a process of differentiation, with initial pick-up of higher-order information overlaid later by additional pick-up of lower-order information, would appear to provide the most powerful explanation for these age differences.

Development can occur along any of a number of parallel paths. Environmental input determines which of these possible routes is most functional, with vision, for example, being chosen for spatial calibration. The ratio between the costs incurred and the gains to be obtained by any transition in development suggests a possible mechanism for that process of transition. These costs and gains will, however, interact at any point in development both with the type of perceptual information to which the infant is then sensitive, and with the particular level of learning predominant at that time. Although the learning may be reversible, if, as in infancy, it is learning of a higher more abstract level which is occurring, once learned there will be irreversible effects on the future direction of development.

The practical implications of this epigenetic process for programmes of intervention are obvious. Intervention, to be successful, must either be early or, if later, must take into account the different nature of the developmental pathway then in operation.

APPENDIX I: RESEARCH PROBLEMS IN WORKING WITH THE BLIND

There are many advantages to be gained in investigations of handicapped infants, in this case those with a particular sensory deficit. The possible practical benefits along with the implications for general theories of development and in particular, perceptual development, are the theme of this thesis. However, the 'front end' of research with handicapped infants is not at all like that of research with normal infants. Infant research has problems of its own, problems which are never discussed in journal articles and which await the new researcher into infant development, perhaps such problems are one of the root causes behind the unrepeatability of much of infant research. Research with handicapped persons also has its problems. It is, however, research with the combination of the two, handicap and infancy, which presents the greatest problems. It seems that in true Gestaltist tradition, the whole is greater than the sum of the parts. It is felt that no researcher should approach this area without first recognising these problems.

The difficulties are many and varied and may change with the type of research design being employed. For instance, cross-sectional research presents a different set of problems from longitudinal research, home visits a different set of problems from visits by infants to the experimental laboratory. It is felt, though, that to achieve some degree of parsimony these problems can be looked at under three main headings of:

(a) ethical;

(b) logistical and practical;

(c) co-operating personnel.

It is recognised that these headings are somewhat artificial with there being a certain amount of overlap between them. There is, furthermore, a degree of covariation between two or more of the areas, for instance ethical problems may generate other logistical problems. Where necessary, therefore, such overlap will be highlighted.

ETHICAL PROBLEMS

The basis of a strong experimental design is that we can compare the effect on a dependent variable of some independent variable. To do this comparison of experimental and control groups is made. Research with the blind or other handicapped group therefore entails some process of subject matching between these groups, usually on the basis of sex, intelligence, mobility, and so on and then measuring the effect of our independent variable. When researching with blind infants the implicit ethical problem involved in this approach is made explicit. This is that if our treatment group is to show any improvement over the control group, then by not providing the control group with the same programme of intervention, we are depriving them of the benefits of the intervention. Yet without this type of control we cannot say whether our intervention with the guide was more beneficial than intervention *per se*. In Chapter 3 I have argued that this suggestion, that it is intervention *per se*, not intervention with the guide, which is causing improvement, can be criticised on both empirical and conceptual grounds. Nevertheless, it is accepted that stimulation in any form for the blind infant is better than none at all (Ferrell, 1980). Without the comparison of experimental and control groups, it becomes more difficult to say just how much that stimulation, through intervention, contributes to the apparent success of sonic-guide intervention.

A second major ethical concern of the researcher is that this type of research does not involve research with *a* subject, but research with a blind infant. We are not dealing with a single subject and his/her problems but a number of subjects - the mother, father, siblings and grand-parents. It is not only the infant who is handicapped. The whole family is necessarily involved in the handicap. Consequently we may be dealing with a whole range of psychiatric problems, a range which is beyond the researcher's abilities. The question is what he does on recognising these problems. With subjects living in foreign countries, it is not a simple matter to arrange that the necessary facilities, for instance psychiatric, go into operation. Nor is it a simple matter to decide in the first place that they *should* go into operation. It may be that what appear to the researcher to be major familial difficulties, may in fact be on the point of being resolved. To introduce help from other sources at this point may be detrimental and possibly set things further back.

This problem is magnified by the fact that in most countries there is no assistance given, other than six-monthly paediatric checks, in coping with blind infants. The amount of assistance from psychologists in those countries which do provide some support is negligible. For most blind infants, it seems that life does not begin until 3 years of age. Despite the protestations of such as Clarke and Clarke (1976), it would appear that by this age, intervention may well be too late other than for assisting the child to develop as a 'normal blind child'. Certainly, the evidence for the qualitatively more beneficial effects of early intervention, provided in this thesis, would suggest that by 3 years of age it may well be too late for successful intervention to occur.

A further problem for the researcher related to the above is that when visited the family will almost certainly still be attempting to come to terms with their infant's handicap. With no external body to turn to, it is inevitable that they turn to the researcher. If the researcher is at the stage of collecting a data base, then any advice he may give will be ad hoc. Others have shown, however, that what appears to be a problem may turn out to be a positive advantage. Schnur and Weihl (1979) have shown that their research efforts with the guide also involved incidental benefits to the subjects involved. They have shown that benefits arising can be anticipated and accurately assessed. They found that much of the content of conversations with the parents reflected, not just concern for the evaluation of the guide, but information seeking on a wide variety of topics. It was found that the mother's perception of the research project reflected anything from providing relief from working alone with the infant, to providing someone with whom the mother could discuss questions about medical back-up, future education and involvement of blind agencies.

What appears at first to be an ethical problem can then turn to the advantage of the subject. For the researcher, too, there are advantages which accrue. By co-operating with the parental concerns, this helps to assuage any doubts the parents may have about the motives of the researcher. This in turn helps to assure the future co-operation of the subject in the research programme. It also allows the researcher to respond to parental concern within any reasonable limits. Schnur and Weihl suggest that assessment and description of these incidental benefits provides data for the researcher as to the eventual use of the guide in the subject's own home surroundings.

This possible benefit of the research programme can only, however, occur with longitudinal studies. For subjects involved in cross-sectional studies the ethical problems presented may be of even greater importance. In the study of school-age children cited in Chapter 2 a common problem which occurred was the noticeable initial hostility of the subjects' teachers to the research programme. It was not difficult to ascertain the reason for this hostility, which was certainly entirely motivated by their concern for the welfare of the children. They wanted immediate answers and expected the researcher to provide them. The collection of information for data was seen as a waste of time, instead their common voice was that "things should be being done!" Trying to explain that "things" cannot be done until the implications of results are determined, can prove to be a difficult task.

For work with these blind infants seen on a short-term basis, the ethical problem for the researcher remains. In this case it has to be explained to the parents that what one is trying to do may be of no benefit to their child but may be of benefit to other infants in the future. It is a large burden of altruism to ask of parents, although all in the studies reported here seemed happy to co-operate in this way. Although seeming happy to co-operate, though, the researcher cannot tell, from a one-off visit, the true expectations that the parents may have had of the session. There is also no way of telling whether such a visit has long-term effects on the parents. If, for instance, their infant did not use the guide, they may harbour thoughts that their infant is worse than other blind infants. It is all too easy for the researcher when engaging in cross-sectional studies not to acknowledge these problems. This is especially the case when he is also engaged in work with normal infants, where the parental demands from the experimental session require no more than a brief background explanation. For the parents of the handicapped child this is clearly insufficient.

The above ethical problems must be given a great deal of consideration before embarking upon a research project with handicapped infants. This type of research is intrusive and time must be spent in deciding whether the possible advantages to be gained in its execution outweigh the possible damaging effects.

PRACTICAL AND ORGANISATIONAL PROBLEMS

Although possibly of less damage to the infant, the problems involved in the logistics of carrying out this type of research are considerable, and may weigh heavily on the outcome of the intervention programme, in the case of longitudinal studies; or, in the case of short-term studies, may affect the results obtained. These problems vary depending on whether the research design is cross-sectional or longitudinal and on whether it is carried out in the lab or in the subject's home.

Results obtained from visits to the lab may be confounded by several factors. Most subjects who visited us travelled from afar with, as mentioned, trips averaging 400 miles. With such trips there are obviously fatigue effects. By the time the infant arrives at the lab he may not be capable of performing well on certain tasks. Results then become difficult to interpret, poor performance possibly being due to inability to use the guide or to simply being too tired. Secondly, with such trips there is a certain amount of anxiety exhibited by the parents, with them coming to an unknown set-up, not knowing what the equipment is for, not entirely aware of what the guide actually does, and in many cases coming from a foreign country. Observations of sighted infants in the lab shows that often the results of first visits are confounded by the infant picking up the mother's anxiety. It would not be surprising if blind infants were also to pick up the parent's anxiety and to manifest it themselves.

By conducting cross-sectional studies in the infant's own home the above problems can, to a great extent, be minimised. The anxiety of the parent is lessened as is the fatigue effect. It is also to some extent more 'natural', in that the infant will have to come to terms with the guide in his own home. If the parents can be shown some successful guide use then they may have something concrete to work with when they begin intervention with the child themselves. There are, however, certain disadvantages in cross-sectional work in the child's own home. Usually the researcher will only have a certain amount of time available to conduct the research. It is quite common to spend one or two hours waiting on the infant waking or being changed or being fed. All of this cuts into the time available for data collection. With long-term subjects this is not such a problem as

activities such as feeding can be incorporated (and can be very usefully incorporated) into sonic-guide work.
Secondly with short-term visits at home the type of data collection is very limited. Many of the tasks which would be performed under controlled conditions in the lab cannot be done. Thirdly, as is seen from the results of Table 3.2, the amount of information which can be collected is limited. This is partly surmountable by adoption of a few meaningful classes of behaviours to be investigated. However, all the information that would be desired cannot be collected.

It would appear that the ideal set-up for the researcher is to have a combination of home and lab visits for a limited number of longitudinal investigations. Lab visits allow accurate assessment of particular behaviours under controlled conditions. For instance radial tracking of objects can be more exactly assessed in the lab. Reaching may be analysed in three dimensions with two-camera set-ups providing more precise information as to abilities in spatial localisation. Combined with the naturalistic observation techniques of home visits this would seem to be the ideal means of investigation of guide use. However, as is seen from Table 3.2, this ideal set-up only appeared to exist with AN. For the other subjects in the sample this optimal combination was not possible. Quite possibly this may have had an adverse effect on the intervention programme and thereby the results obtained. The reason for the greater success was due in part to the proximity of this subject to the researcher.

In all other cases the distance between subjects and researcher militated against a successful venture. To test further the efficacy of guide intervention over a long period, it appears to be necessary that intensive work be done with a large number of infants within a small geographical area.

ENLISTING THE CO-OPERATION AND/OR APPROVAL OF OTHER ASSOCIATED PROFESSIONALS

The third area where problems are incurred in research with the handicapped is in seeking the co-operation of others who are engaged, either directly or indirectly, with the research. Firstly, is the problem of engaging in any multi-disciplinary reasearch, involving professionals of outside bodies. Less obviously, influences of groups concerned with the particular handicap but who do not actively engage in the research may have an effect on the outcome of the research programme. A third possible influence of other personnel on the project is from others within the same discipline as the researcher to whom some of the work on the project has been delegated. In the case of infant guide work not one, but all three, of these possible influences does actively influence the results of the research. Each of these aspects will be dealt with separately.

Despite the apparent attractiveness of a multi-disciplinary approach, involving doctors, nurses, engineers and psychiatrists, the disadvantages of this approach in infant guide research outweigh its possible merits. These other bodies can tell us nothing about whether or not the infant is utilising the guide effectively. The only way we can possibly know this is if we have an expectation of what we should be looking for with each infant age group, not with one age group but with all age groups within infancy. It is felt that only one professional should be dealing with the infant directly in the guide project. That professional should be an infant psychologist who can accurately assess and monitor the infant's development. However, that is not to decry the importance of others co-operating in the project. Ideally, support would be provided from engineers, psychologists and the medical field. Unfortunately few areas can provide all three. In those countries where psychologists are the Cinderellas of the medical profession, there is the additional difficulty of convincing paediatricians that the guide may be useful. Paediatricians have an understandable reluctance to invest faith in something which does not have a long proven history. It may prove difficult to overcome such reluctance.

The second area of concern involves those agencies not actually engaged in the research project, but who may nevertheless have an influence on the running of the project. Such an influence, which is of a more political nature, highlights, if it were to be forgotten, that science is not value-free. Research is not carried out in isolation and various groups have particular stakes in the results of that research. One example of this is the effect on orientation and mobility specialists of guide research. Their attitude is often one of hostility, something which is not surprising considering the impact that large-scale implementation of guide use may have on their own futures. Whether or not such an attitude is to be deplored is not the point at issue, the problem for the researcher is that such an attitude can affect the running of the research programme. Kay (1974) acknowledges that in evaluation of the sonicguide many groups other than the blind have a strong interest; he lists these as blind agencies who are also interested in cost-effectiveness of the project; teachers of the blind, design engineers and "behavioural scientists". In the present study interested groups were of a slightly different type, and, fortunately in Scotland, one occupational therapist, after being convinced of the possible merit of the project, was able to deflect much of this external group pressure.

Last, but of by no means least importance, is the influence on results of those other co-operating psychologists and paediatricians to whom the everyday running was delegated, when travel difficulties occurred. Each psychologist comes to the programme with a particular theory of development, which may either be implicit or explicit. Which particular theory is adopted will have an outcome on the interpretation of results, and on the effectiveness of the intervention programme. Different psychologists will come to the project with different expectations. Those expectations can affect the results obtained. An example will help to illustrate this problem. Suppose the experimenter comes to the project simply to observe rather than to train the infant in guide use. In what situations does he observe the infant? As soon as this question is asked it is seen that observation alone must also subscribe to a particular theory. The situations in which the infant is observed will be determined by whether, for instance, the experimenter is looking for active control of the guide. Moreover the guide is only a machine. It is necessary that, for optimum effectiveness, the developmental requirements of the infant be of primary concern. Certainly, in the example given above, naturalistic observation will be a necessary part of the research programme. It will certainly not be a sufficient one.

APPENDIX II - CONTROVERSY OVER SPECIFICATIONS OF THE SONICGUIDE

In reporting on the engineering parameters of the Sonicguide in Chapter 1, discussion centred around the actual specifications of the guide used. Although it was suggested then that these specifications have caused a great deal of controversy between Kay on the one side and Bower on the other (Bower, 1977 b; Kay, 1978; Kay and Strelow, 1977; Smith and Dailey, 1978) the details of this controversy were not developed. These differences of opinion are not unimportant as they may well determine whether or not guide use takes off. The source of the controversy is the vast difference in scientific backgrounds of the two researchers. Kay, as an engineer, stresses engineering parameters of the guide and, in applying work with the guide to infants, adopts an adult model of "sensation" (based on the doctrine of specific nerve energies). Bower, as a psychologist interested in development, stresses the importance of the sonicguide information in functional and psychophysical terms for the developing infant. The particular specifications of the guide which have aroused debate will now be considered.

DIRECTION:

In discussing this aspect of the guide in Chapter 1, it was pointed out that the characteristics of ultrasound are such that an object located off midline is signalled as being in a slightly different position than if the object itself were emitting the sound. Kay (1977) has suggested that this is a "limitation", and that the I.A.D. should be adjusted so as to match the two. This "limitation" has, however, distinct advantages. The guide provides spatial information through the ears. This information is provided in a series of continuous tones. The question is whether this information interferes in any way with the natural sound information fed in through the ears. This is particularly relevant to speech and consequently language development. It is bad enough to be born blind - which in itself has been linked by some to retardation in language development (Clarke, 1978) - it would be even more tragic if such a child were to suffer additional problems in language development. Ideally, to circumvent this possibility the echoic information supplied by the guide should be separate from other auditory information. An alternative to this would be to utilise the infant's known capacity for divided attention. The infant could then, in a manner similar to the time-sampling of the bat described previously, select which source of auditory information he wishes to attend to. If the mother were talking to her baby wearing the guide, two radial direction indices would be available (unless the mother is straight ahead of the baby), her voice would signal one index and the guide another index. This dislocation has the advantage of the infant being able to attend selectively to the speech of his mother, while also allowing him to check out the mother's location with the guide. It is therefore argued that the exaggerated I.A.D. of the guide used here has a valid functional basis. It is felt that a guide which provides echoic information consonant with "natural" auditory information may well impede language development.

Kay (1978) further argued that there is "every reason for a sensitive code to present problems in the functional development of babies". This he states is due to their motivation to explore their surroundings and constant touching and handling of objects. However this view totally ignores the relation that growth has with auditory localisation. It is the very nature of the "constant handling and touching" which ensures that this relation does not become out of step. Growth of the infant means that there are changes in head size, therefore changes in distance between the ears. This results in changes in time of arrival of sounds at the two ears. On top of this is the growth of the infant's arms in reaching. Is this a problem for the infant? Clearly on a model of development such as that proposed by Kay this would be a problem. Such a model sees infancy as a functionally static period, where differences in time of arrival of sound at the ears is constant for a given position. Such a model is clearly erroneous. What is invariant throughout development is the direction of straight ahead, and to the right or to the left of straight ahead. Variations of positions of sound sources within the sectors left and right must be continually recalibrated. As with the sonicguide information, "natural" information must be <u>interpreted</u> as coming from a certain position. This interpretation depends on the infant's continual recalibration, clearly a rapid process during infancy. The precise specification of the location of a sound source, in a growing infant, depends on right-before-left or left-before-right, time differences. These time differences are continually recalibrated in a dynamic acyive system. It is, in fact, the "motivation to explore" of an active infant which Kay sees as being detrimental, that provides the infant with functional uses of such I.A.D.'s as the guide provides.

FIELD OF VIEW:

Kay (1978) believes that if "maximum attention (coupled with high resolution) is required" it may be that monaural presentation (i.e. the same sound presented at both ears) with a field of 10° would serve. This he sees as being an optimum with infants. Again, with this view, we see the problem of focussing attention on the engineering parameters of the guide as opposed to concentration on the functional utilisation by the subject of the information content of the signals produced by the guide. There are several reasons why implementation of such a field of view would be erroneous. Firstly, it would discount the possibility of guide work with blind neonates. Studies of the development of reaching, which are discussed in Chapter 4, suggest that neonate focal vision is rather poor, although peripheral objects are seen and reached for quite easily. It would be possible that a guide with such a narrow field would result in retardation of reaching.

Related to this is the problem that objects would have to be presented more or less in the midline for them to be in the field of the guide. What happens outside this narrow field when the object becomes imperceptible? This development of the infant understanding of what happens when objects disappear is one of the most important conceptual attainments in infancy (Wishart 1979). With such a restricted field a great deal of the information about objects would be absent. Kay and Strelows (1977) suggestion that, as the infant grows older we simply magnify his available perceptual field, is unacceptable. They provide no information as to how this would affect the infant. Furthermore with such a restricted field the possible social interactions with its mother would be cut down for the infant. The importance of "peek-a-boo" games has been demonstrated by Watson (1966; 1973). Such social interaction games would be impossible with the above field of view. It is not accidental that such behaviours as object concept responses and social interaction games were selected as measures of guide use in the studies reported. These reflect important developmental attainments in infancy.

<u>MOVEMENT</u>:

Although Kay does not see the Doppler effect as being a problem for adults, he does see it to be highly important and disruptive to infant users of the guide. This is particularly so in the acquisition of sensori-motor skills, especially in reaching. He points out that for the blind child there is no possibility of visual examination of hand motion, whereas for the sighted infant "hand grasping is related to visual feedback from the hand as it reaches out". The problem with Doppler shifts is, as Kay sees it, one which requires engineering modification. Using a guide with a distance code of 2 metres and 5 kHz, the range for objects within reach (taken to be approximately 30 cm.) is 0-750 Hz. As the hand moves away from the body towards the object the echoes produced by the moving hand are reduced in pitch. This can cause the sound to become inaudible. The solution, as Kay sees it, is to provide "good sensory aid feedback from the hand as it reaches" (Kay, 1978).

Certainly if reaching did require visual feedback throughout development this would be a problem, although the solution given above is not practical as, as Bower (1977 a) points out, it would require that the infant began his reach with his hand at the centre of his forehead. As the analysis of reaching given in Chapter 4 shows, and as the work of Bower (1979 a) has shown, the sight of the hand is not a prerequisite thr ughout development. Perception of the hand does not play a constant role throughout development. Neonate reaching with sighted babies shows that reaching is visually elicited with the sight of the hand being irrelevant. Later on, the infant finds its hands highly interesting and will engage in a great deal of hand regard. Later still reaching is one-handed with the sight of the hand throughout the reach being unnecessary for the infant. At the end of this stage the hand may compete with the object for the infant's attention. It is this competition between hand and object which highlights the problems with a guide such as that proposed by Kay, with its emphasis on the signals generated by the hand during reaching. The signal produced by the hand will be louder than that produced by the object. As a result the chances of the hand winning out over the object in this phase would be greatly increased. It may then be very difficult to progress from the stage of hand regard and consequently retard reaching even further.

This again shows that too much time and attention paid to the engineering aspects of the guide may divert attention from the functional requirements of the developing child. Doppler shifts do have to be considered in guide use but only in relation to how they interact or interfere at each phase of development.

PERCEPTION OF MORE THAN ONE OBJECT:

Kay states that Bower's use of placing tests to two batons was a particularly unsuitable task to attempt with the guide. The signal generated by the two batons, because they were made of the same material and were at equal distance from the infant, would not produce tones separated by 40 per cent in frequency. Without this separation, Do and Kay (1977) say that the positions of more than one object cannot be determined. This would result in the infant perceiving a baton twice the size of one baton, and in the centre of the two batons. We would therefore expect a reach to the centre of the batons. Instead the infant placed on both batons simultaneously. What can we infer from the infant being able to do this impossible task (in engineering terms impossible)? Two possibilities emerge.

One is that, as Kay alleges, the placing task was not carried out properly - observing rigid experimental protocol. Bower has pointed out that this was not the case, those involved in the task being experienced infant psychologists. The second possibility is more realistic, and concerns two characteristics - one psychophysical and the other functional. Both characteristics are related by the fact that we are dealing, not with a "static system", but with a dynamic organism. The first has to do with the use of head movements by the infant. If two objects are placed at equal distances from the centre, stimulation at the two ears would, as Kay says, be equivalent.

If, though, the infant makes a slight head movement, one object is then closer to the guide than the other. The signals received will then differ in pitch (as the objects are now at different distances). A larger head movement results in one of the objects being lost from the field resulting in the intensity of the stimulus being halved. Precise location of the object is then specified by the degree of head rotation necessary to produce this halving of the intensity.

This functional aspect of use of the guide was not considered by Kay. Nor did his postulated psychophysical requirement, of 40 per cent separation of tones, take into account the work by Kohler (1956), who found a correlation as low as 0.20 between audiometric variables and discrimination of objects.

SUMMARY:

It is recognised that if it were not for the technological competence of engineers, then no artificial echolocation work with the blind would be possible. In this light it may appear that excessive criticism has been made throughout this section of Kay and his co-workers. It is, however, felt that an orientation which does not consider the developmental requirements of the infant may have two outcomes - both of which are disadvantageous. One is to make the plight of the blind child worse. Or, secondly, to miss out on the possible advantages to be gained simply because of not being able to make sense of the infant's responses while wearing the guide.

APPENDIX III - DIAGNOSIS OF BLINDNESS[1]

The term "blindness" is not an homogeneous one. Some of those who are designated as totally blind may have some minimal vision depending on the criterion for total blindness. Within the U.K., the Royal National Institute for the Blind designate as totally blind many who have more vision than simply light perception. This poses several difficulties, two of which are important in the present series of studies. The first difficulty is that parents may then treat their infant as blind in that they may feel there is little they can do for him until school is begun. It is possible, as has been suggested previously in the text, that this may lead to a generalised lack of stimulation resulting in passivity. As this difficulty is discussed in the text it is only briefly mentioned here and later in the discussion. A second difficulty which is of importance in sonicguide research is that infants, who are not in fact totally blind, may be referred for sonicguide intervention. The nature of the relationship between degree of blindness and later cognitive lesions is not yet known. It does not appear that it is a linear relationship between "percentage of blindness" and "percentage of cognitive lesions". Instead it appears that even minimal residual vision, enough to discriminate shadows

[1] I am grateful to Dr. Irene Neilson for allowing me access to visit the subjects MP and JT at several intervals, and for providing access to videotapes of her own visits.

may be sufficient to enable development to proceed on a sighted schedule, rather than on a blind schedule.

It is, therefore, clearly of crucial importance that initial assessment of blindness be accurate. In testing infants this assessment can be difficult. One cannot ask the infant to point to objects, try form discrimination tests and so on. As with many fields in psychology, the answer seemed to lie in adopting a reductionist approach, utilising the techniques of electrophysiology (Brindley, 1970). Three major electrophysiological techniques are used in medical ophthalmology.

(a) Electro-oculography (E.O.G.) This is used for recording the resting potential of the retina. The technique was originally used for measuring eye movements or nystagmus, but can be employed to record the change in retina resting potential with light and dark adaptation. Abnormal light-induced changes in E.O.G. indicate that one or more of the following factors are at fault: retinal receptors (rods and cones); pigment epithelium; receptor pigment; choroidal malfunctioning. Rodieck (1974) regards that the value of an E.O.G. lies in its objectivity, and that recordings are possible in very young infants under general anaesthesia.

(b) Electro-retinogram (E.R.G.) E.R.G. recordings are made by application of an electrode on the cornea with a reference electrode on the forehead. The recording of the waveform obtained is made up of a number of smaller wave components which indicate malfunction in a number of areas. (Ikeda and Friedmann, 1972.) E.R.G.'s are sensitive enough to identify even minor functional loss of the retina. As with the E.O.G., the E.R.G. can be performed on young infants under general anaesthetic.

(c) Visually evoked responses (V.E.R.) With normal E.O.G. and E.R.G., subjects may still be blind due to lesions in the "higher neurones" such as in the visual cortex or lateral geniculate body. V.E.R. recordings can pick this up by obtaining electrical responses from the occipital pole. Stimuli used may be of "flash" form, for those with extremely poor acuity, or line edge stimuli to pick up pattern vision.

Use of these three techniques in electrophysiology of the visual system provides what is widely regarded as the most objective and precise measure of blindness by detecting specific functional losses in the visual system. Their use with infants is additionally valuable in enabling an objectivity of measurement which would not otherwise be possible. Parents are usually the first to detect visual deficiency in their infant although they often do not know it is a visual deficiency, just that "something is wrong" (for instance Subject NN reported in Chapter 3). Use of such accurate measures would then be of value in detecting, and diagnosing accurately, blindness early in life. However, this reliance on electrophysiological techniques does not seem to have the "factual", "scientific" or "objective" merit that is claimed for it. The cases of twin subjects MP and JT (discussed in Chapter 2) will be considered as they are of interest in the evaluation of electrophysiological techniques.

ASSESSMENT The parents of these infants first contacted the hospital at 3 to 4 months of age when they had thought that something was wrong with their sight. They had at first been told that there was nothing wrong, but, on a later visit, were told that both were totally blind, blindness being due to Leber's congenital amaurosis. The ophthalmic report was of no recordable E.R.G. under photopic conditions. Under scotopic conditions a recording was obtained of 3-4 microvolts in each subject, as opposed to a normal finding of 150-250 microvolts (artefacts of 25 microvolts have been recorded in other subjects). The report pointed out a variety of other factors, such as no V.E.R., indicating that both were totally blind.

Despite this the parents had reported that one of the infants was capable of picking up small objects from the floor. As has been reported, when they visited the lab for testing as to the applicability of a sonicguide they were found to have some residual vision. JT played freely with toys, pursuing them when they rolled away from him. The smallest object he could locate was a 2.5 cm. cube. His reaching was undisturbed by masking any sound coming from the toy. When placed in darkness he would not reach at all for noise-making or silent objects; in fact, in darkness he became distressed, like many sighted infants. The other subject, MP, although less visual than his brother, could still respond to some visual inputs. The smallest object he reached for when visually specified was 8 x 5 cm. Below that size, no reaching was elicited. This behavioural evidence of residual functioning vision is certainly at odds with the electrophysiological evidence. It appeared that, though these infants were physiologically blind, they were psychologically sighted.

It was thought that, rather than providing them with sonicguides it would be more effective to further explore their residual vision. To this end, Dr. I. Neilson has visited them on a once-weekly basis. Her reports showmthat use of vision has progressed dramatically since the first visit. JT is able to reach accurately for objects as small as 5 mm. diameter. Colours are named correctly with ease, size discrimination can be performed on shapes with surfaces of 1 cm^2 versus 2 cm^2. Adults dressed similarly with similar features can be quickly identified at distances up to 2 metres. Recently it has been suggested by the ophthalmologist that corrective lenses may be prescribed. MP is less visual than his brother and appears to be less willing to use his vision, preferring to allow JT to do things for him. His locomotion is markedly different from JT. Small objects are, however, reached for and colours can be named, although he seems somewhat lazy in performing these tasks.

DISCUSSION Despite electrophysiological evidence of total blindness these children were able to see. This suggests that the researcher working with the guide be cautious in acceptance of physiological/ophthalmological evidence of total blindness. It is felt that behavioural tests utilising techniques established in work with sighted infants should be used in those cases where there is doubt as to degree of blindness - obviously excluding such cases as anophthalmic infants. The evidence from physiology is not more objective or factual.

A second point which is of some importance is the fact that intervention by a psychologist was successful in promoting the use of their residual vision. A third child, LF, mentioned in Chapter 2, also showed some degree of residual vision. No intervention programme was implemented with this child, with the parents treating her in the way they thought a blind baby should be treated. That child now shows no use of her vision and behaves like a "normal totally blind child". She cannot walk and shows no sign of speech other than limited humming. Although admittedly a limited subject pool from which to draw any firm conclusions, this evidence highlights the importance of the initial diagnosis of blindness. Recourse to electrophysiology should not, it is argued, be the sole means of providing a diagnosis. This type of diagnosis may easily provide false negatives. In this case false negatives may result in a self-fulfilling prophecy of what to expect from a blind child. This recourse to so-called "objectivity" may then have a damaging effect on the development of the child. It is necessary to reiterate that science does not exist in isolation. The effects of the diagnosis of blindness may be long-term. This means that the initial diagnosis must be extremely precise. The degree of precision necessary is not, it would appear, provided by electrophysiology.

It may be argued that if we were to attempt electro-physiological diagnosis now, we may obtain evidence of visual functioning. This point is, however, not relevant. If not for the psychological evidence for residual vision this second attempt would not have been considered. If the original physiological diagnosis had been accepted by the parents and they had treated the children accordingly then these children may well have developed as LF did. Secondly, there would be no value in attempting the procedure again. Aside from the fact that it is a painful procedure, there would be nothing gained in terms of telling the parents or interventionists what to do about their developmental needs. It would simply be an academic exercise.

It may also be argued that the reason for the negative recordings was due to lack of technological sophistication. This argument would go on to state that at present the techniques are not yet available to permit this degree of accuracy. This is possibly true. However, again the argument is not relevant. If the techniques are not available at present, which others would certainly dispute (Lombogo et al, 1969; Arden et al, 1973), then any reporting to the parents and others concerned should reflect this degree of uncertainty. If no recognition is taken of this uncertainty, then the diagnosis will stand as being the final word on the infant being blind. The consequences of this may be considerable.

REFERENCES

ADELSON, E. & FRAIBERG, S.,
1974 Gross motor development in infants studied blind from birth. Child Dev. 45: 114-126.

ADELSON, E. & FRAIBERG, S.,
1976 Sensory deficit and motor development in infants blind from birth. In, Z.F. Jastrzenbska (ed.) The effects of blindness and other impairments on early development. New York: Amer. Found. for the Blind.

AITKEN, S. & BOWER, T.G.R.,
1981 The Use of the Sonicguide in Infancy. In press in Journal of Visual Impairment and Blindness.

AITKEN, S. & BOWER, T.G.R.,
1981 Intersensory substitution in the blind. In press.

ALEGRIA, J. & NOIROT, E.,
1978 Neonate orientation behavior toward human voice. International Journal of Behavioural Development, 1: 291-312.

ALEGRIA, J. & NOIROT, E.,
1980 On early development of oriented mouthing in infants. CNRS Conference, Royamount, France. June 15-18.

ALLEN, T.W., WALKER, K., SYMONDS, L. & MARCELL, M.,
1977 Intrasensory and intersensory perception of temporal sequences during infancy. Dev. Psychology 13: 225-229.

ARDEN, G.B. et al.,
1973 Br. J. Ophthal. 13: 203.

ARONSON, E. & ROSENBLOOM,
1971 Space perception in early infancy: perception within a common auditory-visual space. Science 172: 1161-3.

BAHRICK, L.E.,
1980 Infants perception of substance and temporal synchrony information in multimodal events. Paper presented at Int. Conf. on Infant Studies, New Haven.

BALL, W. & TRONICK, E.
1971 Infant responses to impending collision: optical and real. _Science_, _171_, 818-820.

BÉKÉSY, G. von,
1955 Human skin perception of travelling waves similar to those on the cochlea. _J. Acoustical Society of America_. _27(5)_ 830-841.

BEKESY, G. von,
1967 _Sensory Inhibition_.
Princeton University Press.

BELL, A. G.
1900 Giving eyes to the ears of the blind. Dictated at Washington D.C. April 11, 1900. Reported in Beinn Bhreagh Recorder. April 26, 1910.

BIRCH, H.G. & LEFFORD, A.
1963 Intersensory development in children. _Monographs of Society for Research in Child Development_. _28_ Whole no. 89.

BIRCH, H.G. & LEFFORD, A.
1967 Visual differentiation, intersensory integration, and voluntary motor control. _Monographs of Society for Research in Child Development_. _32_, 2 (Serial no. 110)

BLANK, M. & BRIDGER, W.H.
1964 Cross-modal transfer in nursery-school children. _J. Comparative & Physiological Psychology_. _58_, 277-282.

BORING, E.G.
1942 _Sensation and perception in the history of psychology_. New York, Appleton-Century-Crofts.

BORNSTEIN, M.H.
1979 Two kinds of perceptual organization near the beginning of life. _Minnesota Symposium on Child Psychology_ 18 October, 1979.

BOWER, T.G.R
1966 Slant perception and shape constancy in infants. _Science_, 1966, _151_, 832-4.

BOWER, T.G.R., 1972 — Object perception in infancy. <u>Perception</u> <u>1</u>: 15-30.

BOWER, T.G.R., 1974a — The Evolution of Sensory Systems. In <u>Essays in Honour of J.J. Gibson</u>. R.M. McLeod & H.L. Pick (eds.) Cornell University Press.

BOWER, T.G.R., 1974b — <u>Development in Infancy</u>. San Francisco: Freeman. (1981 2nd edition in press)

BOWER, T.G.R., 1977a — Blind babies see with their ears. <u>New Scientist</u> <u>73</u>:(1037) : 255-257.

BOWER, T.G.R., 1977b — Babies are more important than machines. <u>New Scientist</u> <u>23rd June</u>: 712-714.

BOWER, T.G.R., 1977c — Visual development in the blind. Unpub. m/s.

BOWER, T.G.R., 1977d — Comments on Yonas et al. "Development of sensitivity to information for impending collision". <u>Perception & Psychophysics</u> <u>21</u>(3): 281-282.

BOWER, T.G.R., 1977e — The development of reaching in infants. Unpub. monograph. Univ. of Edinburgh.

BOWER, T.G.R., 1977f — Pathways in development. <u>Studies in the Learning Sciences, 4</u>. Paris: OECD Publications.

BOWER, T.G.R., 1977g — Concepts of development. Paper read at 21st International Congress of Psychology, Paris. In <u>Proceedings of 21st Int. Cong. Psych</u>. Paris: Presses Universitaires de France, 1978.

BOWER, T.G.R., 1979a — <u>Human Development</u>. San Francisco: Freeman.

BOWER, T.G.R.,
1979b Intersensory coordination or differentiation - a comment on some recent papers. Unpub. monograph.

BOWER, T.G.R.,
1979c Visual development in the blind child. In Smith & Keen (eds.) Visual Handicap in Children. Spastics International Medical Publications. London: Lavenham Press.

BOWER, T.G.R.,
1979d The origins of meaning in perceptual development. In A.D. Pick (ed.) Perception and its development: A Tribute to E.J. Gibson. Hillsdale, N.J. : Laurence Erlbaum Ass.

BOWER, T.G.R., BROUGHTON, J.M. & MOORE, M.K.,
1970a Demonstration of intention in the reaching behaviour of human neonates. Nature 228: 679-680.

BOWER, T.G.R., BROUGHTON, J.M. & MOORE, M.K.,
1970b Infant response to approaching objects: an indicator of response to distal variables. Perception and Psychophysics 9: 193-196.

BOWER, T.G.R., BROUGHTON, J.M. & MOORE, M.K.,
1970c The coordination of vision and touch in infancy. Perception and Psychophysics 8: 51-53.

BOWER, T.G.R. & DUNKELD, J.,
1979 Textural occlusion. Unpub. m/s.

BOWER, T.G.R., DUNKELD, J. & WISHART, J.G.,
1979 Infant perception of visually presented objects. Science 208: 1137-8.

BOWER, T.G.R., WATSON, J.S. & UMANSKY, R.,
1979 Auditory surrogates for vision. Unpub. m/s.

BOWER, T.G.R. & WISHART, J.G.,
1972a Stages in the development of the object concept. Cognition 1(1).

BOWER, T.G.R. & WISHART, J.G.,
1972b The effects of motor skill on object permanence. Cognition 1: 165-172.

BRINDLEY, G.S. et al.,
1969 Cortical blindness and the functions of the non-geniculate fibres of the optic tracts. J. Neural. Neurosurg. Psychiatry. 32: 259-264.

BRUNER, J.S.,
1968 Processes of cognitive growth: Infancy. Worcester, Mass. : Clark University.

BRUNER, J.S. & KOSLOWSKI, B.,
1972 Visually preadapted constituents of manipulatory action. Perception 1: 3-15.

BRUNER, J.S. & MAY, A.,
1972 Cup to Lip. New York: Wiley.

BRYANT, P.E. et al.,
1972 Recognition of shapes across modalities by infants. Nature 240: 303-4.

BUTTERWORTH, G. & CASTILLO, M.,
1976 Coordination of auditory and visual space in neonates. Perception 5: 155-160.

CARON, A.J., CARON, R.F. & CARLSON, V.R.,
1979 Infant perception of the invariant shape of objects varying in slant. Child Dev. 50: 716-721.

CHANGEUX, J.-P. & DANCHIN, A.,
1976 Selective stabilisation of developing synapses as a mechanism for the specification of neural networks. Nature 264: 705-712.

CLARKE, E.,
1978 From gesture to word: On the natural history of deixis in language acquisition. In Human Growth in Development. J.S. Bruner & A. Garten (eds.) Oxford: Clarendon Press.

CLARKE, A.M. & CLARKE, A.D.B.,
1976 Early Experience: Myth and Evidence. London: Open Books.

COHEN, J.L.
1966 Effect of blindness on children's development. New Outlet for the Blind. 60(5) 150-4.

COTZIN, M. & DALLENBACH, K.M.,
1950 Facial Vision: The Role of Pitch and Loudness in Perception of Obstacles by the Blind. American Journal of Psychology: 63 485-515.

DAVENPORT, C.B.
1944 Postnatal development of the human extremities. Proceedings of American Philosophical Society. 88(5) : 375-475.

DAY, R.H. & MACKENZIE, B.E.,
1973 Perceptual shape constancy in early infancy. Perception 2 : 315-321.

DEKABAN, A.S.,
1972 Mental Retardation and Neurologic Involvement in patients with Congenital Retinal Blindness. Dev. Child Neurol. 14:436-444.

DEKABAN, A.S. et al.
1966 Congenital Amaurosis of Retinal Origin. Archives Neurologica . 14 : 294-301.

DI FRANCO, D., MUIR, D. & DODWELL, P.,
1978 Reaching in very young infants. Perception 7 : 385-392.

DO, M.A. & KAY, L.,
1977 Resolution in an artificially generated multiple object auditory space using new auditory sensation. Acoustica 36 : 9-15.

DOBELLE, W.H. et al.,
1976 "Braille" reading by a blind volunteer by visual cortex stimulation. Nature 259 : 111-112.

DODDS, B.
1979 Lip-reading in infants: attention to speech presented in and out of synchrony. Unpub. m/s.

DODWELL, P.C., DI FRANCO, D. & MUIR,
1976 Responses of infants to visually presented objects.
Science 194 : 209-211.

DREVER, J.,
1955 Early Learning and Perception of Space.
American Journal of Psychology 68 : 605-614.

DUNKELD, J. & BOWER, T.G.R,
1978 Quantitative and qualitative differences in Smiles of 6-12 weeks.
Unpub. m/s.

DUNKELD, J. & BOWER, T.G.R.,
1980 Infant response to impending optical collision. Perception (9) : 549-554.

ESCALONA, S.
1976 Quoted in Adelson, E. & Fraiberg, S. (1976) Sensory deficits and motor development in infants blind from birth. In JASTRZENBSKA, Z.F. (ed.) The effects of blindness and other impairments on early development. Amer. Found. for Blind : New York.

ETTLINGER, G. & BLAKEMORE, C.B.
1967 Cross-modal matching in the monkey.
Neuropsychologia 5 : 147-154.

FERREL, K.A.
1980 Can Infants use the Sonicguide? Two years experience of Project VIEW!
J. Vis. Imp. & Blindness 209-220.

FERRELL, K.A. & LICAMELE, W.L.
1980 Sensory aid intervention and its effect on the development of blind infants and toddlers.
Paper presented at Amer. Acad. Child Psychiatry; Chicago : October 1980.

FIELD, J.
1976 Relation of young infants reaching behaviour to stimulus distance and solidity. Dev. Psych. 12(5): 444-448.

FIELD, J.,
1977 Coordination of vision and prehension in young infants. Child Dev. 48: 97-103.

FIELD, J., DI FRANCO, D., DODWELL, P. & MUIR, D.,
1979 Auditory-visual coordination in 2½-month-old infants. Journal of Infant Behaviour 2: 113-122.

FIELD, J., MUIR, D., PILON, R., SINCLAIR, M. & DODWELL, P.,
1980 Infants orientation to lateral sounds from birth to 3-months. Child Dev. 51: 295-298.

FINE, S.R.,
1979 Incidence of Visual Handicap in Childhood. In V. Smith & J. Keen (eds.) Visual Handicap in Children.

FISH, R.M.,
1971 A new auditory display for the blind. Unpub. m/s.

FISH, R.M.,
1972a A T.V. to audio conversion system for coding pictures for the blind. Unpub. m/s.

FISH, R.M.,
1972b Method of coding complex shapes by an auditory display. Unpub. m/s.

FISH, R.M.,
1975 Visual substitution systems: control and information processing considerations. Unpub. m/s.

FISH, R.M.,
1976a An audio display for the blind. Unpub. m/s.

FISH, R.M.,
1976b An electronically generated audio display for the blind. Unpub. m/s.

FRAIBERG, S.,
1968 Parallel and divergent patterns in blind and sighted infants. Psychoanalytic Study of the Child XXIII: 264-301.

FRAIBERG, S.,
1975 The development of human attachments in infants blind from birth. M.P.Q. 21(4) : 315-334.

FRAIBERG, S.,
1977 Insights from the Blind. London: Souvenir Press.

FRAIBERG, S. et al.,
1969 An educational programme for blind infants. Journal of Special Education 3(2) ; 121-139.

FRAIBERG, S., SIEGEL, B. & GIBSON, R.,
1966 Role of sound in the search behaviour of a blind infant. Psychoanalytic Study of the Child. Vol. XXI : 327-357.

FREEDMAN, D.G.,
1974 Human Infancy: an evolutionary perspective. Hillsdale, N.J. : Erlbaum.

GAZE, R.M.,
1970 The Formation of Nerve Connections. London: Academic Press.

GIBSON, E.J.,
1969 Principles of Perceptual Learning and Development. London: Appleton-Century-Crofts.

GIBSON, E.J. & SPELKE, E.S.,
1981 Perception and attention. In press. To appear in J. Flavell (ed.) Carmichael's Manual of Child Psychology.

GIBSON, J.J.,
1950 The Perception of the Visual World. Boston: Houghton-Mifflin.

GIBSON, J.J.,
1966 The theory of information pick-up. Unpub. m/s.

GUILFORD, J.P.,
1956 Fundamental Statistics in Psychology and Education. New York: McGraw-Hill.

HAITH, M.M.,
1969 Infrared T.V. recording and measurement of ocular behaviour in the human infant. American Psychologist 24: 279-283.

HARRIS, P. & MACFARLANE, A.,
1974 The growth of the effective visual field from birth to 7 weeks. J. Experimental Child Psychology, 18 : 340-348.

HARTLAGE, L.C.,
1968 Deficit in space concepts associated with visual deprivation. J. Learning Disabilities 1(11) : 649-651.

HATWELL, Y.,
1966 Privation sensorielle et Intelligence. Paris: Universitaires de France.

HEBB, D.O.,
1949 The Organisation of Behaviour. New York: Wiley.

HEIDER, F.,
1912 N.V.

HEIN, A. et al.,
1970 Development and segmentation of visually controlled movement by selective exposure during rearing. J. Comparative & Physiological Psychology 73(2) : 181-187.

HEIN, A. & DIAMOND, R.M.,
1972 Locomotory space as a prerequisite for acquiring visually guided reaching in kittens. J. Comparative & Physiological Psychology 81(3): 314-318

HELD, R.,
1965 Plasticity in sensory-motor systems. Scientific American 213(5) : 84-94.

HELD, R. & BAUER, J.A.,
1967 Visually guided reaching in infant monkeys after restricted rearing. Science 155 : 718-720.

HELD, R., & HEIN, A.,
1963 Movement-produced stimulation in the development of visually guided behaviour. J. Comparative & Physiological Psychology 56: 872-876.

HINDE, R.A.,
1966 Animal behaviour: a synthesis of ethology and comparative psychology. New York: McGraw-Hill.

HOFSTEN, C. von,
1977 Binocular convergence as a determinant of reaching behaviour in infancy. Perception 6: 139-144.

HOFSTEN, C. von,
1979 Recalibration of the convergence system. Perception 8: 37-42.

HOFSTEN, C. von,
1980 Eye-hand coordination in the new-born. Unpub. m/s.

HORNBOSTEL, E.M. von,
1925 The Unity of the senses. (Translated by E.Kaffka & W.Vinton) In W.D.Ellis (ed.) A source book of Gestalt psychology. London: Routledge & Kegan Paul.

IKEDA, H. & FRIEDMANN, A.I.,
1972 Electro-oculography, electro-retinography and the visual evoked response. Modern Ophthalmology, A. Sorsby (ed.) London: Butterworth.

JASTRZENBSKA, Z.F., (ed.)
1976 The effects of blindness and other impairments on early development. New York: American Foundation for the Blind.

JUURMAA, J.,
1970 On the accuracy of obstacle detection by the blind. New Outlook for the blind 64(3):65-72

KAY, L.,
1966 Binaural sensory aid. In R. Dufton (ed.) Proceedings of international conference on sensory devices for the blind. London: St. Dunstan's.

KAY, L.,
1973a Sonic glasses for the Blind - a progress report. Amer. Found. for Blind Research Bull. 25 : 25-28

KAY, L.,
1973b The Design and evaluation of a sensory aid to enhance spatial perception of the blind. Electrical Engineering Report No. 21 University of Canterbury, Christchurch New Zealand.

KAY, L.,
1973c The Sonic glasses evaluated. New Outlook for the Blind (Jan.) 67(1) : 7-11.

KAY, L.,
1974a Toward objective mobility evaluation: Some thoughts on a theory. Amer. Found. for the Blind. P.55.

KAY, L.,
1974b Orientation for blind persons: Clear path indicator or environmental sensor. New Outlook for the Blind 68(7) : 289-296.

KAY, L.,
1974c A sonar aid to enhance spatial perception for the Blind: engineering design and evaluation. The Radio & Electronic Engineer 44 : 605-627.

KAY, L.,
1978 The Sensory parameters of the binaural sensory aid. Unpub. m/s.

KAY, L. & STRELOW, E.,
1977 Blind babies need specially designed aids. New Scientist : 23rd June, 709-712.

KELLOGG, W.N.,
1962 Sonar system for the blind. Science 137 : 399-404.

KIRTLEY, D.D.,
1975 The Psychology of Blindness. Chicago : Nelson Hall.

KOHLER, I.,
1956 Orientation by Aural Cues.

KOHLER, W.,
1929 Gestalt Psychology.
New York : Liveright.

LANGER, J.,
1970 Werner's comparative organismic theory. In Mussen, P.H. (ed.) Carmichael's Manual of Child Psychology. New York: John Wiley.

LASKY, R.E.,
(1978 pre-print) Reaching for real and virtual objects by 3 and 6 months olds.

LEE, D.N.,
1974 Visual information during locomotion. In H.L. Pick & R.B. Macleod (eds.) Essays in honour of J.J. Gibson. Ithaca, N.Y. : Cornell Univ. Press.

LESLIE, A.M.,
1979 Representation of perceived causal connection in infancy.
Unpub. Ph.D. Thesis : Oxford Univ.

LEWIS, M. & BROOKS, J.,
1974 Infants' social perception: A constructivist view.
In Infant Perception: from Sensation to Cognition. Vol. II
L.B. Cohen & P. Salapatek (eds.)
New York: Academic Press.

LICKLIDER, J.C.R.
1950 Basic correlates of the auditory stimulus. In S.S. Stevens (ed.) Handbook of experimental psychology.
New York: Wiley.

LOMBROSO, C.T. et al.,
1969 E.E.G. Clin. Neurophysiology 27: 238.

LYONS-RUTH, K.,
1977 Bimodal perception in infancy: response to auditory-visual incongruity. Child Devt. 48: 820-7.

McDONNELL, P.,
1975 Development of visually guided reaching. Perception & Psychophysics 18(3) 181-5.

MCDONNELL, P.M.,
1979 Patterns of eye-hand coordination in the first year of life.
Canadian Journal of Psychology 33: 253-267.

MCDONNELL, P.M. & ABRAHAM, W.C.,
1979 Adaptation to displacing prisms in human infants.
Perception 8 :175-185.

MCDONNELL, P.M., ANDERSON, V.E.S. & ABRAHAM, W.C.,
1979 Asymmetry and orientation of arm movement. Unpub. m/s.

McGURK, H., TURNURE, C. & CREIGHTON, S.J.,
1977 Auditory-visual coordination in neonates.
Child Development 48 : 138-143.

MELTZOFF, A.N. & BORTON, R.W.,
1980 Intermodal matching by human neonates.
Nature 282(5737) : 403-404.

MENDELSON, M.J. & HAITH, M.M.,
1976 Relation between audition and vision in human newborn.
Mono. Soc. Res. Ch. Devt. 41 No. 167.

MENTEN, J.M. & COHEN, L.R.,
1979 Infant perception of auditory-visual synchrony.
Presented at meeting of American Psychological Association. Sept. 1979.

MICHOTTE, A.
1963 The perception of causality.
New York : Basic Books.

MILLAR, W.S.
1975 Visual attention to contingent and non-contingent stimulation in 6- and 9-month old infants.
Psychological Research 37: 309-319.

MIMS, F.M.,
1973 Sensory aids for blind persons.
New Outlook for the Blind 67(9) : 407-414.

MUIR, D. & FIELD, J.,
1979 Newborn infants orient to sounds.
Child Development 50 : 431-436.

O'CONNOR, N. & HERMELIN, B.,
1972 Seeing and hearing and space and time. Perception and Psychophysics 11: 46-8.

O'CONNOR, N. & HERMELIN, B.,
1978 Seeing and Hearing: Space and Time. London: Academic Press.

OSGOOD, C.E. et al.,
1957 The Measurement of Meaning. Urbana, Illinois: Illinois Univ. Press.

PAINE, R.S. & OPPE, T.E.,
1966 Neurological examination of children. Clinics in Developmental Medicine. Nos. 20 & 21: Lavenham Press.

PAPOUSEK, H.,
1967 Experimental studies of appetitional behaviour in human newborns and infants. In H.W. Stevenson, E.H. Hess & H.L. Rheinoold (eds.) Early Behaviour. New York: Wiley.

PAPOUSEK, H.,
1969 Individual variability in learned responses in human infants. In R.J. Robinson (ed.) Brain and early Behaviour. London: Academic Press.

PAPOUSEK, H.,
1972 Appetitional behaviour in neonates. In H.W. Stevenson, E.H. Hess & H.L. Rheinoold (eds.) Early Behaviour: Comparative and developmental approaches. New York: Wiley.

PAPOUSEK, H.,
1979 From adaptive responses to social cognition: The learning view of development. In M.H. Bornstein & W. Kessen (eds.) Psychological Development from Infancy: Image to Intention. Lawrence Erlbaum Associates.

PIAGET, J.,
1936 The Origins of Intelligence in Children. London: Routledge and Kegan Paul, 1953. (Original French edition, 1936).

PIAGET, J.,
1937 — The Construction of Reality in the Child. London: Routledge and Kegan Paul, 1954. (Original French edition, 1937)

PIAGET, J.,
1978 — Behaviour and Evolution. Pantheon: New York.

PILLSBURY, W.B.,
1934 — The Fundamentals of Psychology(3rd ed.). New York: Macmillan.

PRATT, K.C., NELSON, A.K. & SUN, K.H.,
1930 — The Behaviour of Newborn Infants. Columbus, Ohio: State Univ. Press.

PRAZDNY, S.,
1980 — A computational study of a period of infant object-concept development. Perception 9: 125-150.

RADEMAKER, G.G.J.,
1931 — Das Stehen. Berlin: Julius Springo (from Walters & Webb)

RADER, N., OPALUCH, R. & JOHNSON, K.,
1979 — Reaching for objects in neonates. Unpub. m/s.

RICE, C.E. & FEINSTEIN, S.H.,
1965 — Sonar system of the blind: size discrimination. Science 148: 1107-1108.

RIESER, J., LOCKMAN, J.J. & PICK, H.L.,
1978 — The role of experience in knowledge of spatial layout. Unpub. m/s.

ROCK, I. & HARRIS, C.S.,
1967 — Vision and touch. Scientific American 216: 96-104

RODIECK, R.W.,
1974 — The vertebrate retina - principles of structure and function. Freeman: Reading.

ROWELL, D. et al.,
1970 — Ph.D. and M.A. theses. Dept. of Electrical Engineering, University of Canterbury.

RUFF, H.A. & HALTON, A.,
1978 Is there directional reaching in the neonate? Dev. Psychology 14(4): 425-6.

SCHNUR, R. & WEIHL, C.,
1979 Incidental benefits to research subjects in technological aid development. Journal of Visual Impairment and Blindness 73(5): 197.

de SCHÖNEN, S.
1980 Development de la coordination visuo-manuelle et de la lateralisation manuelle des conduites d'atteinte et de prise d'objet. Travaux du Centre d'Etude des Progressus Cognitifs et du Langage. CNRS - L.P. 802.

SCOTT, B.L.
1978 Speech as patterns in time. In R.A. Cole (ed.) Proceeding of 14th Conf. on Cognition. Carnegie-Mellon Univ. Pittsburgh.

SCOTT, B.L. & De FILIPPO, C.L.,
1979 Development of a tactile aid for the reception of speech. Unpub. m/s.

SELIGMAN, M.E.P.,
1975 Helplessness. San Francisco: Freeman.

SENDEN, M. VON,
1960 Space and sight. London: Methuen (orig. pub. 1932)

SIEGEL, S.
1956 Non-parametric statistics for the behavioural sciences. Tokyo: McGraw-Hill.

SIMMONS, J.A., HOWELL, D.A. & SUGA, N.
1975 Information content of bat sonar echoes. American Scientist 63: 204-215.

SIQUELAND, E.R. & LIPSITT, L.P.,
1966 Conditioned head-turning in human newborns. J. Experimental Child Psychology 3: 356-376.

SMITH, R.P. & DAILEY, R.H.,
1978 Sonicguide: A valuable aid for Blind Children and Infants. Unpub. m/s.

SPELKE, E.,
1976 Infants intermodal perception of events. Cognitive Psychology 8: 553-560.

SPELKE, E.S.,
1978 Intermodal exploration by 4-month old infants: Perception and knowledge of audio-visual events. Unpub. PH.D. Thesis: Cornell Univ.

SPELKE, E.S.,
1979 Exploring audible and visible events in infancy. In A.D. Pick (ed.) Tribute to E.J. Gibson.

SPELKE, E.S. & OWSLEY, C.,
1979 Intermodal Exploration and Perceptual Knowledge in Infancy. Infant Behaviour and Development 2: 13-27.

SPERRY, R.W.,
1956 The eye and the brain. Scientific American 194(3): 48-52.

SPIGELMAN, M.N.,
1976 A comparative study of the effects of early blindness on the development of auditory-spatial learning. In Z.F. Jastrzenbska(ed.) The Effects of blindness and other impairments on early development. New York: American Found. for Blind.

STRAUSS, S. & STAVY, R.,
1979 U-Shaped Behavioural Growth: Implications for Theories of Development. In W.W. Hartup(ed.) Review of Child Development Research. University of Chicago Press.

STRELOW, E.R., KAY, N. & KAY, L.,
1978 Binaural sensory aid: Case studies of its use by two children. Visual Impairment and Blindness. Jan.: 1-9

STRELOW, E.R., KAY, N. & KAY, L.,
1979 Binaural sensory aid.
(Reply to Smith & Dailey) Unpub. m/s.

SUPA, M., COTZIN, M. & DALLENBACH, K.M.,
1944 Facial vision; the perception of obstacles by the blind.
Amer. J. of Psychology 57: 133-183.

THOMSON, J.,
1977 Maps, programmes and the visual control of locomotion.
Unpub. Ph.D. Thesis: Edinburgh Univ.

TREVARTHEN, C.B.,
1974 The psychology of speech development.
In E.H. Lenneberg (ed.) Language and brain: developmental aspects.
Neurosciences Research Program Bull. 12: 570-585.

TREVARTHEN, C.B.,
1975 Basic patterns of psychogenetic change in infancy.
Proceedings of O.E.C.D. Conference on "Dips in Learning". St. Paul de Vence.

TURKEWITZ, G. et al.,
1966 Effect of intensity of auditory stimulus on directional eye movements in the human neonate.
Animal Behaviour 14: 93-101.

VAIZEY, M.J. et al.,
1977 Neurological abnormalities in congenital amaurosis of Leber. Arch. Diseases in Childhood 52: 399-402.

WALTERS, C.P. & WALK, R.D.,
1974 Visual placing by human infants.
J. Exp. Child Psych. 69(1): 34-40

WARREN, D.H. & PICK, H.L.,
1970 Intermodality relations in localisation in blind and sighted people. Percept. and Psychophysics 8(6): 430-432.

WATSON, J.S.,
1966 The development and generalisation of "contingency awareness" in early infancy: Some hypotheses.
Merril-Palmer Quarterly 12: 123-135.

WATSON, J.S.,
1973 Smiling, Cooing and the Game. _Merrill-Palmer Quarterly_ _18_: 323-339.

WERNER, H.,
1948 _Comparative psychology of mental development_. Chicago, Illinois: Follett.

WERTHEIMER, M.,
1961 Psychomotor coordination of auditory and visual space at birth. _Science_ _134_: 1692.

WHITE, B.W. et al.,
1970 Seeing with the skin. _Perception & Psychophysics_ _7_: 23-29.

WHITE, B.L., CASTLE, P. & HELD, R.,
1964 Observations on development of visually-directed reaching. _Child Devt_. 35: 349-364.

WHITE, B. & HELD, R.,
1966 Plasticity of sensori-motor development in the human infant. In J.R. Rosenblith & W. Allinsmith (eds.) _The Causes of Behaviour_. Boston: Allyn and Bacon.

WISHART, J.G.,
1979 Development of the object concept. Unpub. Ph.D. thesis: Edinburgh Univ.

WISHART, J.G., BOWER, T.G.R. & DUNKELD, J.,
1978 Reaching in the dark. _Perception_ _7_: 507-512.

WOHLWILL, J.F.,
1973 _The Study of Behavioural Development_. New York: Academic Press.

WORCHEL. P. & DALLENBACH, K.M.,
1947 Facial vision: perception of obstacles by the deaf-blind. _Amer. J. of Psychology_ _60_: 502-553.

YONAS, A. et al.,
1977 Development of sensitivity to information for Impending Collision. _Perception & Psychophysics_ _21_: 97-104.

ZAPOROZHETS, A.V., 1965

The development of perception in the pre-school child.
In P.H. Mussen (ed.) <u>European Research in Cognitive Development</u>.
<u>Mono. of Soc. Res. in Child Dev</u>. <u>30</u>(2).

ERRATA

BOWER, T.G.R., 1966b Heterogeneous summation in human infants. Animal Behaviour 14 : 395-398.

COHEN, L.B., 1973 A two-process model of infant visual attention. Merril-Palmer Quarterly 19 : 157-180.